THE JOURNAL OF DENTAL RESEARCH

(Continuing the Journal of the Allied Dental Societies)

A journal of stomatology; devoted to the advancement and dissemination of knowledge pertaining to the mouth and teeth, and to their relations to the body as a whole

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Presenting a summary of the titles of the papers, and the names, degrees, and professional relationships of the authors, with abstracts or interpretations of the original matter in each communication.

These abstracts are neither editorials nor criticisms; they do not contain comment beyond the scope of the papers to which they refer. They are intended solely to give the reader a general though clear idea of what the corresponding authors have chiefly to say.

(*This section of the introductory matter in this volume presents, consecutively, all the abstracts that were published under the head of "contents" at the front of each of the four numbers in the volume. The unrelated miscellaneous items of temporary interest that accompanied the abstracts in the quarterly issues have been eliminated from this presentation of the abstracts.*)

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I. Papers in the Main Body of the Volume: Pages 1–720

An experimental study, with certain "vital dyes," of the persistent teeth of the albino rat. By John S. Marshall, M.D., Sc.D., F.A.C.S.; Captain, U. S. Army, Retired. (Anatomical Laboratory of the University of California, Berkeley, Cal.)..... 1

Marshall injected, into living rats, various relatively non-toxic dyes, such as trypan blue and dianil blue, and then, after suitable allowances of time for the absorption and dissemination of the pigments, killed the rats and noted the distribution of the coloring matters in the various parts of the incisor teeth—the method of "vital staining." The bearing of such studies on problems of the development and microscopic structure of teeth, and of the nutrition of normal and pulpless teeth, is obvious. The "vital stains" were injected intra-abdominally. Rats were selected for this study, because their incisor teeth "grow continuously during the life of the animal; they have no roots, but grow from a persistent pulp; and, consequently, the cells concerned in the formation and development of the various structures of a tooth can be studied from the earliest period of their formation to their complete development."

Marshall found that the dyes passed into alveolar bone, pericementum, cementum, pulp, dentin, and "*forming*" enamel (into the rods but not into the interprismatic substance, nor into the "ampullae" at the dento-enamel junction). The dyes, after each injection, fade and tend gradually to disappear entirely from every part of a stained tooth.

Besides presenting his data on the distribution of the injected dyes, Marshall also discusses his findings on the histology of the incisor teeth of the rat.—(W. J. G.)

The disinfection of the oral mucosa with crystal violet and brilliant green. By C. COLEMAN BERWICK, A.B. (George William Hooper Foundation for Medical Research, and Research Laboratories of the Dental Department of the University of California, San Francisco, Cal.. 21

The scope of Berwick's study may be seen at a glance in the summary on page 21. He found, in many tests that are described in detail and supported by numerous data, that brilliant green and crystal violet, in solution together (1 per cent of each in 50 per cent alcohol), are effectively antiseptic in the mouth, where, in such a solution, they exert very little if any harmful effect on any of the oral mucous membranes. These dyes act together, in such solutions, not only as an efficient antiseptic, but also as "a mild stimulus to newly forming granulations, both by keeping down contamination by oral organisms, and by either destroying or inhibiting the growth of organisms initially present."

Berwick alludes to the undesirable effects, on the oral tissues, of alcohol (dehydration) and of tincture of iodine (blistering), in the range of strengths in which each is effectively antiseptic. He believes he has found that the alcoholic solution of brilliant green and crystal violet referred to above (1 per cent of each in 50 per cent alcohol) is superior, for antiseptic purposes, to alcohol or iodine.—(W. J. G.)

Oral sepsis and internal medicine. By LEWELLYS F. BARKER, M.D., Professor of Clinical Medicine, Johns Hopkins University, Baltimore, Md.. 43

A very interesting and instructive review of the knowledge of different kinds of disease that may be associated, or causally connected, with oral sepsis, from the viewpoint of one of the most experienced observers in, and practitioners of, medicine. Barker

discusses various diseases in this relation under the heads of diseases of the locomotor system, respiratory apparatus, circulatory apparatus, blood and blood-building organs, digestive system, urogenital system, nervous system, and endocrinic and metabolic systems. The review is concluded with a discussion of the necessity for, and difficulties in the way of, close coöperation between physicians and dentists. The review presents, in a clear and compact style, and with the comprehension of a master, the essential facts in present-day knowledge of the very important subject to which it is devoted. (A report of a discussion of this paper is presented on page v, in the section on proceedings.)—(W. J. G.)

Concerning human cementum. By A. HOPEWELL-SMITH, Sc.D., L.R.C.P., M.R.C.S., L.D.S., Professor of Dental Histology, Histopathology, and Comparative Odontology, School of Dentistry, University of Pennsylvania, Philadelphia, Pa..... 59

A timely review of the knowledge of human cementum from a histological point of view and in the light of the author's own researches and his extended experience; presented with special reference to the problem of the nutrition of a pulpless tooth. The various branches of the subject of the histology of human cementum are discussed clearly and effectively under the following heads: Origin (formation and development), distribution, dimensions, relationships to enamel, chemical composition, histology, histo-pathology, functions, and clinical significance. (A report of a discussion of this paper is presented on page xiii, in the section on proceedings.)—(W. J. G.)

Progressive dentistry and stomatology. 2. Periodontology, with special reference to periodontoclasia. By ARTHUR H. MERRITT, D.D.S., Chairman of the Committee on Scientific Investigation and Nomenclature of the American Academy of Periodontology, New York City..... 77

Merritt indicates, in direct and concise style, in a comprehensive way, and from a fund of special information on the subject, the progress and status of knowledge of the etiology, pathology, and treatment, of "loose teeth," variously designated as Riggs' disease or pyorrhea alveolaris, and now—under the guidance of the American Academy of Periodontology—known as *periodontoclasia*. Summaries of current conflicting views regarding the etiology and most effective treatment of periodontoclasia are in-

cluded. Under the head of "conclusions" (page 84), Merritt refers, in this relation, to the outstanding features of our knowledge on one side and of our ignorance on the other, and points the way to greatly needed research in the latter direction. A valuable bibliography is appended.—(W. J. G.)

The origin and evolution of the human dentition. (A palaeontological review.) **Part I.—Stages of ascent from the Silurian fishes to the mammals of the Age of Reptiles.** By WILLIAM K. GREGORY, Ph.D., Associate Professor of Vertebrate Palaeontology, Columbia University; Associate in Palaeontology, American Museum of Natural History, New York City..... 89

A masterly review of palaeontological facts bearing on the origin and evolution of the teeth in man, by one of the best informed investigators in this field. Fully illustrated with reproductions of photographs and drawings of classical importance. The scope of this scholarly study may be seen at a glance in the summary on page 89. The author "begins at the beginning, or as near to the beginning as the palaeontological record extends" and, in this first part of his detailed review, traces the evolution of dentition from the fishes of Silurian and Devonian times to the mammals of the Age of Reptiles. The author's "summary and conclusions for part I," beginning on page 166, is an excellent abstract of this part of the review. (Part II, in continuance from this point, is published on pages 215 to 283.)

This review presents a complete summary of the main facts in the palaeontological record on the origin and evolution of human dentition; and will be universally regarded as the most notable and successful effort to epitomize this information, to reveal its full evolutional import, and to suggest its practical significance.—(W. J. G.)

Newell Sill Jenkins. (An appreciation.) By EDWIN T. DARBY, D.D.S., M.D., LL.D., Emeritus Professor of Operative Dentistry, School of Dentistry, University of Pennsylvania, Philadelphia, Pa..... 187

An interesting and appealing sketch of the life of Dr. Jenkins and the important part he took in the development of dentistry. In a personal tribute to his departed friend, Dr. Darby sums up the character and achievements of Dr. Jenkins in this significant comment: "*His life was spent in acts of kindness and deeds of love*"—the key to the respect and affection in which Dr. Jenkins was regarded by all who knew him.—(W. J. G.)

The John R. Callahan Memorial Fund. By T. IRVING WAY, D.D.S., Chairman of the Memorial Committee of the Ohio State Dental Society, Cincinnati, Ohio..... 193

Way presents a statement of the plan of the Ohio State Dental Society to "perpetuate the memory of the late John R. Callahan, in recognition of his contributions to the science and art of dentistry, and his unselfish devotion to its advancement throughout the many years of his professional life." It is proposed by the Memorial Committee that a Bronze Memorial be erected on the grounds of the Cincinnati General Hospital; also that a Callahan Research Fund be established, the income from which shall be awarded "from time to time to the person making the best contribution to the science and art of root-canal problems," the fund and award to be under the direction of a standing committee of the Ohio State Dental Society, and the prize to be known as the John R. Callahan Award. The Committee considers that the sum of $10,000 will be needed adequately to execute this plan, and invites subscriptions from individuals and societies. The report presents a list of the names of the contributors and the sums contributed, amounting to a total of $5,092.60.—(W. J. G.)

The Endowment Fund for the support of the Journal of Dental Research. (Fifth report). By WILLIAM J. GIES..... 195

This statement presents the names of thirty additional contributors to the Fund and reports an increase of $645.15 in the amount paid into it, one hundred and fifty-four subscribers having paid $3,311.15, which, with accrued interest ($71.66), makes the Fund a total of $3,382.81. Of this amount, $3,350.00 are held in U. S. securities at rates of interest ranging from 3.5 per cent to 5.5 per cent. *There have been no expenditures from the Fund.* The next succeeding report is published on page 325.—(W. J. G.)

Ciliated epithelium in a granuloma. By GUTHRIE MCCONNELL, M.D., Superintendent of Laboratories, Research Institute of the National Dental Association, Cleveland, Ohio..... 197

The author discusses briefly the origin of the squamous epithelium that is commonly found in granulomas and as the lining membrane of apical cysts. In the case reported, in addition to the above type of epithelium, an area of ciliated columnar cells is present on the external surface of the granulomatous mass. Two possible sources of these cells are mentioned: the granu-

loma (a) perforated the floor of the antrum of Highmore, and the mucous membrane lining that cavity grew over the invading tissues; or, it (b) was derived from an embryonal remnant of the first visceral arch from which both the upper and lower jaws are developed.—(G. McC.)

Calcification in the pulp of teeth affected by pyorrhea, with an outline of a method of demonstrating the presence of tubules in the calcified portions of such pulp. By ALPHONSE LANG, Histologist, and GUTHRIE MCCONNELL, M.D., Superintendent of Laboratories, Research Institute of the National Dental Association, Cleveland, Ohio..... 203

The authors call attention to the factors that are supposed to be concerned in the deposit of calcium salts in degenerated tissues. The composition of deposits of these salts is practically the same, whether laid down under normal conditions (ossification) or as a result of pathological changes. The chief difference among such deposits seems to be a lack of regularity in the formation of those that are produced in broken down tissues. Deposits of the latter kind occur when the amount of necrotic tissue is too great to be absorbed.

Calcareous deposits in the pulp may be divided into two classes: those that are attached to the walls of the pulp cavity and those that are free in the pulp. The former are more or less physiological in character, for such deposits are continuous to a large degree with the primary dentin. The second group represent a more distinctly pathological condition, calcification occurring in the pulp tissue as a result of infection and of circulatory disturbances. The history in these cases is that of a slowly developing lesion.

According to previous observers, such calcareous deposits in the pulp have not had any definite structure. A study of the pulp shows, however, that the odontoblasts are very important cells, whose functions are similar to those of the osteoblasts, which, when stimulated, cause a deposit of calcium salts. The authors studied one hundred teeth from cases of pyorrhea, none of the teeth showing cavity formation. Twenty of these exhibited free calcification in the pulp. The ordinary laboratory methods revealed no definite structure but, by the use of a special technic, each of the twenty specimens of pulpal calcification showed the

presence of tubules. The authors explain this formation on the assumption that during the degenerative changes in the cells, the odontoblasts were stimulated to perform their normal function. Fibrils were sent out, around which the salts were deposited and the tubules formed. The special method employed to reveal this tubular structure is given in detail, so that the findings may be verified by other investigators.—(G. McC.)

The origin and evolution of the human dentition. (A palaeontological review.) **Part II.—Stages of ascent from the Paleocene placental mammals to the lower primates.** By WILLIAM K. GREGORY, Ph.D., Associate Professor of Vertebrate Palaeontology, Columbia University; Associate in Palaeontology, American Museum of Natural History, New York City..... 215

This part of Gregory's important and well illustrated review continues directly Part I, published on pages 89 to 183, inclusive. The scope of the review may be seen at a glance in the summary on page 215. The author's "summary and conclusions for Part II," beginning on page 267, is an excellent abstract of this part of the review. (Part III, in continuance of the review, is published on pages 357–463.)

The entire review is a great fund of important facts and opinions in dental science, and must be *studied*, particularly in close comparison of the text with the many exceptional illustrations, to be fully appreciated.—(W. J. G.)

A further statement regarding "a plan to compile and publish authentic information and authoritative opinion on problems concerning pulpless teeth and pulp devitalization." ELMER S. BEST, D.D.S., Minneapolis, Minn..... 285

This "further statement" (in extension of the author's remarks on page 523 of volume I of this JOURNAL) presents a list of the questions in the questionary that Best has recently issued; and includes an invitation, to all who may be interested, to coöperate before October 1, 1920, in the important work he has undertaken in this relation.—(W. J. G.)

Experimental studies of the validity of advertised claims for products of public importance in relation to oral hygiene or dental therapeutics. 3. Mennen's Cream Dentifrice, advertised as an acid dentifrice, is alkaline in reaction. By MAXWELL KARSHAN,

A.M., Assistant in Biological Chemistry, School of Medicine, Columbia University, and WILLIAM J. GIES..... 293

The authors find that Mennen's Cream Dentifrice is not an acid dentifrice. *Its reaction is alkaline.* Any power that Mennen's Cream Dentifrice may have, to "soften and break down deposits of tartar and . . . . mucin 'plaques,'" and to "stimulate the flow and (increase the) alkalinity of saliva," must be due to some other agency than the advertised, though non-existent, acidity of this dentifrice.—(W. J. G.)

Experimental studies of the validity of advertised claims for products of public importance in relation to oral hygiene or dental therapeutics. 4. Pepsodent "Bulletin No. 4" does not show that Pepsodent exerts appreciable digestive action on dental mucin plaques. By WILLIAM J. GIES..... 299

In a discussion of "Bulletin No. 4," issued July 23, 1919, by the Pepsodent Company, the author shows that the data in the "Bulletin" demonstrate only that Pepsodent *contains* pepsin. This has not been denied. The "Bulletin" fails to show, however, that Pepsodent, *as Pepsodent*, and used *as a dentifrice*, has any digestive power whatever on mucin plaques *on the teeth.*

The methods for the determination of the *presence* of pepsin in Pepsodent, described by the author of the "Bulletin," involve either (a) the removal of pepsin from Pepsodent and the subsequent *concentration* of that pepsin in a given solution, or (b) the preliminary elimination, from Pepsodent, of the basic (*neutralizing*) abrasive.

The pepsin is "activated," in each method, not (as might be expected from the claims made in Pepsodent advertisements) with acid calcium phosphate but *by the direct addition of an excess of strong acid, lactic or hydrochloric,* even in the presence (in one method) of acid calcium phosphate. This procedure is equivalent to an admission, by the author of the "Bulletin," that he knows that the acid calcium phosphate in Pepsodent does not effectively activate the pepsin in that dentifrice. "Bulletin No. 4" does not refute any of the criticisms of Pepsodent published by Franke and Gies, it merely ignores them. —(W. J. G.)

Experimental studies of the validity of advertised claims for products of public importance in relation to oral hygiene or dental therapeutics. 5. May the use of Pebeco Tooth-Paste, twice a

day, be reasonably regarded as a part of "the basis of correct oral hygiene?" Part I.—Preliminary tests of the relative toxicity of potassium chlorate for tadpoles and newts. By WILLIAM J. GIES..... 313

The criticism of the use of potassium chlorate in dentifrices, such as Pebeco, published in the December, 1919, number of this JOURNAL, led the writer to endeavor to determine *experimentally* the truth in the matter at issue. The results of the *preliminary* study—a series of experiments on tadpoles and newts—are described in this paper.

These animals were selected for the preliminary tests because they offered special opportunity, immersed in the solutions under investigation, to study the general absorbability of potassium chlorate through animal membranes, and the consequent toxicity of this substance, in direct comparison with other compounds. It was found that potassium chlorate was somewhat more toxic than common salt, but much less poisonous than common soaps or sodium arsenite, and very much less destructive than mercuric chloride. Potassium chlorate was also *less injurious than potassium sulfocyanate!* These results indicate that potassium chlorate is not an "*extremely*" dangerous drug and that the use of such dentifrices as Pebeco is not attended by "*grave*" perils, so far as the content of potassium chlorate is concerned. These conclusions are supported by the results of tests on higher animals, some of which are reported on page 511.—(W. J. G.)

The Endowment Fund for the support of the Journal of Dental Research. (Sixth report.) By WILIAM J. GIES..... 325

This statement presents the names of nineteen additional contributors to the Fund and reports an increase of $343.00 in the amount *paid* into it, one hundred and seventy-three subscribers having *paid* $3,654.15, which, with accrued interest ($113.95), makes the Fund a total of $3,768.10. Of this amount, $3,750.00 are held in U. S. securities at rates of interest ranging from 3.5 per cent to 5.5 per cent. *There have been no expenditures from the Fund.* The next succeeding report is published on page 531.—(W. J. G.)

A classification of teeth the diseased pulps and apices of which are related to infective focal and systemic sequelae. By CLARENCE J. GRIEVES, D.D.S., Baltimore, Md..... 327

Grieves presents a comprehensive review of the situation involving diseased dental pulps, apical infections, and related systemic diseases. He writes from the standpoint of an experienced observer working closely in collaboration with physicians who are equally as earnest as he in establishing the truth in this field where dentistry and medicine are in very close practical affiliation. The scope of this scholarly review may be seen at a glance on page 327. Grieves' classification is given in detail on pages 330 and 331. The author sums up his views in ten numbered conclusions which appear here and there, on pages 329 to 352, as indented paragraphs, and which collectively are an effective abstract of the review. (A discussion of the paper is reported on page xxxv, in the section on proceedings of societies.) —(W. J. G.)

The origin and evolution of the human dentition. (A palæontological review.) **Part III.—Nature's earlier experiments in evolving large-eyed and short-jawed primates.** By WILLIAM K. GREGORY, Ph.D., Associate Professor of Vertebrate Palæontology, Columbia University; Associate in Palæontology, American Museum of Natural History, New York City..... 357

This part of Gregory's exceptionally complete review continues directly the second part published on pages 215 to 283, inclusive. The scope of the review may be seen at a glance in the summary on page 357. The author's "summary and conclusions for Part III," beginning on page 424, is an excellent abstract of this part of the review. (Part IV, in continuance of the review, is published on pages 607–717.)—(W. J. G.)

A plea for a standardized technique for oral radiography, with an illustrated classification of findings and their verified interpretations. By FRANKLIN W. MCCORMACK, Radiographer, San Francisco, Calif..... 467

McCormack's description of his "standardized technique for oral radiography," and his "classification of findings" and "interpretations," are presented with the collaboration of the nine San Francisco dentists named on page 484. The paper expresses ideas that McCormack, as a radiographer, and his collaborators, as dentists, have evolved from their extended experiences, obtained clinically and in comprehensive research. The scope of the paper may be seen at a glance in the summary on page 467. "The dental conditions that may be recognized in and correctly

interpreted from accurate radiograms, as verified clinically or experimentally," are summarized in some detail on page 484. Nine plates at the end of the paper present a series of radiographs that illustrate the verified findings in the nine groups of dental conditions specified in the classification. The research referred to in the paper has been done, in part, in collaboration with investigators in the University of California, and is being continued and extended.—(W. J. G.)

Experimental studies of the validity of advertised claims for products of public importance in relation to oral hygiene or dental therapeutics. 6. May the use of Pebeco Tooth-Paste, twice a day, be reasonably regarded as a part of "the basis of correct oral hygiene?" Part II.—Tests of the relative toxicity of potassium chlorate after intravenous injection into albino rats. By WILLIAM J. GIES 511

In continuance of the study of the relative toxicity of potassium chlorate, in this instance by careful injection (in solutions of equipercentage concentration, at a standard rate) of specific amounts of the compared substances, into the venous circulation of albino rats under uniform dietary and environmental conditions, it was found that a given weight of potassium chlorate was markedly *less toxic* than the same weight of each of such substances of physiological occurrence as sodium nitrite, castile soap, sodium oleate (a soap), potassium chloride, and potassium sulfocyanate, but was very much *more toxic* than sodium chloride or *sodium chlorate* (!). The general results agree with those obtained in the previous study of relative toxicity for tadpoles and newts; and they indicate that potassium chlorate is not an "*extremely*" dangerous drug and that the use of such dentifrices as Pebeco is not attended by "*grave*" perils, so far as the content of potassium chlorate is concerned. The relative non-toxicity of *sodium* chlorate (less, per unit of weight, than that of common salt) raises the question whether any benefits that may accrue to the individual from the dentifricial use of *potassium* chlorate cannot be more advantageously derived from the use, instead, of the very much less poisonous *sodium* chlorate. The author's conclusions are summarized on page 527.—(W. J. G.)

The Endowment Fund for the support of the Journal of Dental Research. (Seventh report.) By WILLIAM J. GIES 531

This statement presents the names of twenty-one additional contributors to the Fund and reports an increase of $306.00 in the amount *paid* into it, one hundred and ninety-four subscribers having *paid* $3,960.15, which, with accrued interest ($113.95), makes the Fund a total of $4,074.10. Of this amount, $4,000 are held in U. S. securities at rates of interest ranging from 3.5 per cent to 6 per cent. *There have been no expenditures from the Fund.* The next succeeding report is published on page 719. —(W. J. G.)

Samuel James Meltzer. In memoriam 534

We record the recent death of S. J. Meltzer, one of America's most eminent men of science, and an editor, for physiology, of this JOURNAL. The originals of the portrait and signature, on page 534, were selected for our use, at our request, by Dr. Meltzer's son-in-law, Dr. John Auer, one of the editors for pharmacology.—(W. J. G.)

A microscopic study of pulps from infected teeth. By ARTHUR T. HENRICI, M.D., Associate Professor of Bacteriology, and THOMAS B. HARTZELL, M.D., D.M.D., Assistant Professor of Bacteriology, College of Medicine, University of Minnesota, Minneapolis, Minn 537

In a previous paper (JOURNAL OF DENTAL RESEARCH, 1919, i, p. 419), Henrici and Hartzell presented results of bacteriological studies which indicated that, "in nearly one-half the number of cases where (clinically vital) teeth or their investing tissues are infected, bacteria . . . . are already present in the pulp tissues;" and that "the presence of these bacteria in the pulp must be accompanied by some chronic inflammatory changes in the tissues." The present paper describes a continuance of these studies, and presents and illustrates the microscopic findings for pulps from forty-one *clinically vital* teeth, thirteen of which teeth "showed pyorrhea alone, five were invaded by caries without pyorrhea, and twenty-three exhibited evidences of both caries and pyorrhea." The authors have found evidence of the occurrence of active inflammation in fourteen pulps from forty-one infected *clinically vital* teeth—37 per cent of the number.

These important results afford a substantial basis for the opinion, as expressed by the authors, that "the pulp is frequently invaded by microörganisms long before it has been exposed by

caries or, indeed, in the absence of caries, by organisms which have passed into the pulp from the gingival region; and that such invading organisms give rise in the pulp to localized areas of inflammation which are not necessarily suppurative or gangrenous in nature, but rather granulomatous and progressive, leading to ffbrosis or other changes. When suppuration and gangrene finally occur, it is in a tissue which has long been subjected to injury by milder types of infection, and suppuration is here merely the final stage of the process."—(W. J. G.)

Comment on McCormack's "plea for a standardized technique for oral radiography." By C. EDMUND KELLS, D.D.S., New Orleans, La. 551

In a criticism of the paper recently published by McCormack (JOURNAL OF DENTAL RESEARCH, 1920, ii, p. 467), Kells writes that McCormack's technique has not been *standardized* in all respects, especially in the Coolidge-tube procedure and in the development of the films. Kells alludes to the fact that it was not explained *how* McCormack "*reproduced* sets of radiograms after intervals of three years." He is unable to understand "McCormack's disposition of the shadows of the malar bones." In his discussion of McCormack's statements of "conditions that may be recognized in, and correctly interpreted from, accurate radiograms," Kells directly denies the validity of some of McCormack's conclusions. He feels that "it is incumbent upon McCormack to explain . . . . . *how* he can differentiate between a vital pulp and an empty canal;" and "*how* he tells that a filling is a deep one and not merely a veneer." See the next succeeding abstract.—(W. J. G.)

Reply to Kells' comment on McCormack's "plea for a standardized technique for oral radiography." By FRANKLIN W. MCCORMACK, Radiographer, San Francisco, Cal. 557

Replying to the comment by Kells (preceding abstract), McCormack states that "no claim was made that the technique described by me (him) is an exact or an absolute one; but the mechanical manipulation of equipment, tubes, and dark-room procedure, is so standardized, and the fixed rules operate with such slight deviations, that the work would become purely mechanical if it were not for the physical variations in patients." McCormack remarks that, "if the reproduction of radiograms after an interval of time is of sufficient interest to warrant the

publication of a paper with half-tone reproductions of the radiograms, and photographic illustrations of the various procedures that must be used to explain the text," he will "gladly prepare such a paper." McCormack explains, in greater detail, his method of preventing the occurrence of a radiographic shadow of the malar process over the apices of the upper molar teeth. Although admitting the force of some of the remainder of Kells' criticisms, McCormack defends his position on practically all the points at issue and suggests that "if Dr. Kells . . . . would differentiate between the terms *interpretation* and *diagnosis*, a great light might strike him." "Interpretation," says McCormack, "calls the attention of the diagnostician to the changes from normal that the radiograms show; and the radiogram, plus the radiographer's interpretation, give radiographic findings. *These findings must be checked clinically and verified before a diagnosis can be made.*"—(W. J. G.)

A medicated tooth-paste, with a full statement of its composition. By ALEXANDER LOWY, Ph.D., Assistant Professor of Organic Chemistry, School of Chemistry, University of Pittsburgh, Pittsburgh, Pa. 565

A brief statement regarding "F. E. I." tooth-paste, with an indication of its *complete* chemical composition. Dentists are invited to prepare this new tooth-paste and to try it for themselves, pending the publication by the author and his collaborators of the results of a clinical study of it now in progress.—(W. J. G.)

Progressive dentistry and stomatology. 3. The problem of devitalized (dead) teeth. By JOSEF NOVITZKY, D.D.S., San Francisco, Cal. 567

A general statement of the danger of the development of systemic diseases from the retention of non-vital teeth. Novitzky contends that every tooth with a non-vital pulp, or without a pulp, is a *dead* tooth—that such a tooth receives no nourishment, whatever. He states that examinations of hundreds of devitalized teeth have shown "that every one of such teeth, if left in the jaws, *was infected within six months of the time of devitalization.*" The author presents an illustrated description of his method for the thorough surgical removal of devitalized (dead) teeth and associated foci of infection, involving "removal of the corresponding buccal plate of bone," and appends a list of

his related publications since 1914. Much of the author's research in this field was done in the Medical Department of the Leland Stanford, Jr., University under the guidance there of Dr. F. E. Blaisdell, Professor of Surgery. See the next succeeding abstract.—(W. J. G.)

Progressive dentistry and stomatology. 4. Comment on Novitzky's discussion of "the problem of devitalized (dead) teeth." By M. L. RHEIN, M.D., D.D.S., New York City..... 579

Rhein contents, in direct disagreement with Novitzky (preceding and succeeding abstracts), that "it can be sanely asserted that a large percentage of teeth with non-vital pulps can be so treated as to leave them free to function, without any danger of such teeth becoming factors in focal infection." Recalling Novitzky's statement that non-vital teeth are inevitably infected within six months of the time of devitalization, Rhein argues that, if Novitzky refers to bacteriologic examinations of such teeth *while the teeth were firmly held in the alveolar process*, Novitzky's "observations mean that none of the teeth was properly treated." Rhein believes that teeth with non-vital pulps, as treated by his own method, have not come within the scope of Novitzky's observation in this regard. Rhein states that "again and again bacteriologic tests of root canals ready for filling have given negative results. This statement applies also to canals where some reaming of the gutta-percha has been done months or years after the root filling had been inserted. Finally," he adds, "we can show roentgenographs of teeth covering a period of twenty years (and of some for a period of thirty years, where there were no initial pictures), in which we see the signs of perfect root fillings and of alveolar structures in apparently ideal physiologic condition in the periapical region. These facts entirely refute the views of Novitzky in this relation." Rhein insists that a tooth "remains a vital organ so long as the cementum receives nourishment through the pericementum. Only if and after the pericementum ceases to function, can such a tooth be correctly called a *dead* tooth."

Rhein suggests that "the removal of the buccal plate of bone for the purpose of extracting a tooth through this orifice," as outlined by Novitzky, "has been recommended from time to time for many years." Rhein regards this procedure as doubtful in utility in all but "certain special cases." "It is ques-

tionable," he adds, "whether currettement of the average case requiring it cannot be done as effectively through the socket as by way of a buccal opening." See the succeeding abstract. —(W. J. G.)

Progressive dentistry and stomatology. 5. Reply to Rhein's comment on Novitzky's discussion of "the problem of devitalized (dead) teeth." By JOSEF NOVITZKY. 585

The facts adduced by Rhein (preceding abstract), and which, in Rhein's belief, "entirely refute the views of Novitzky," are, according to Novitzky, *proof* of nothing in this relation. Novitzky adds: "(a) A negative bacteriologic test from a canal *ready for filling* means nothing. (b) Reamings of gutta-percha cannot afford evidence of the state of the tooth matrix, which is a far better culture medium than medicated gutta-percha. (c) Roentgenographs do *not* show the presence or absence of infection, nor do they always distinguish calcification from ossification. What many writers point to as a filling-in of bone is not a physiological condition but a *pathological* state. The deposition of blood salts and broken-down bone around the apex of a dead tooth should not be mistaken for newly-formed bone." Novitzky states also: "My position is difficult because I cannot say that I have examined teeth treated by Rhein, or by any one of the 'hundreds of dentists' who have been instructed by him in his technic. I have, nevertheless, examined dead teeth that were most carefully and skilfully treated precisely according to the technic publicly advocated by him and have found all these teeth to be infected. . . . . I have found nothing to convince me that Streptococcus viridans will not be found ensconced at the root ends of dead teeth 'hermetically' sealed by Rhein, just as they occur at the root ends of dead teeth treated by less clever operators than he."

In further direct allusion to Rhein's criticism, Novitzky remarks: "'The statement that a 'tooth remains a vital organ, so long as the cementum receives nourishment through the pericementum,' is positively disproved by the fact that young cementum was deposited on a replanted tooth that had been boiled before replantation. A boiled tooth is certainly dead. It is not true that a pulpless tooth 'is retained in the alveolus *because* life continues in a portion of the pericementum.' The truth is, as has been pointed out frequently, that all dead teeth, including those

that have been boiled, are retained because of the deposition of cementum on their roots."—(W. J. G.)

A success or failure in bridge-work: which? By CHARLES F. ASH, D.D.S., New York City 591

Ash states briefly the original dental condition of his patient, the nature of his diversified treatment, the character of the appliances provided, and the status of affairs at the termination of the treatment and at the end of the eighth year thereafter. The original conditions, the progress of the treatment, and the outcome are progressively illustrated in detail. The author does not answer the question he raises in the title, but those who discussed the paper (see page liii, section on proceedings) concluded that the treatment was a great success in practically all respects.—(W. J. G.)

The origin and evolution of the human dentition. (A palæontological review.) **Part IV.—The dentition of the higher primates and their relationships with man.** By WILLIAM K. GREGORY, Ph.D., Associate Professor of Vertebrate Palæontology, Columbia University; Associate in Palæontology, American Museum of Natural History, New York City 607

This part of Gregory's exceptionally complete review continues directly the third part, published on pages 357 to 465, inclusive. The scope of the review may be seen at a glance in the summary on page 607. The author's "summaries and conclusions for part IV," beginning on page 690, present an excellent abstract of this part of the review. (Part V, in conclusion of the review, will be published in the first issue of Volume III.)

In this part of the review, the author considers many of the facts of human dentition that relate particularly to the latest phases in the evolution of the teeth in man.—(W. J. G.)

The Endowment Fund for the support of the Journal of Dental Research. (Eighth report.) By WILLIAM J. GIES 719

This statement presents the names of eighteen additional contributors to the Fund and reports an increase of $861.00 in the amount *paid* into it, two hundred and twelve subscribers having *paid* $4,821.15, which, with accrued interest ($211.98), makes the Fund a total of $5,033.13. Of this amount, $4,700 are held in U. S. securities at rates of interest ranging from 3.5 per cent to 6 per cent. *There have been no expenditures from the Fund.*—(W. J. G.)

II. Papers in the Supplementary Section of the Volume; Proceedings of Dental and Stomatological Societies: Pages xvii–xxxii

On the surgical treatment of suppurative gingivitis, so-called pyorrhea. By Arthur Zentler, D.D.S., Instructor, Advanced Courses in Dentistry, Columbia University, New York City... xvii

The author defends his method for the surgical treatment of suppurative gingivitis and responds to some of the criticisms directed against the utility of his technique.—(W. J. G.)

Announcement by the Oral Hygiene Committee of the First District Dental Society of the State of New York. By Arthur Zentler, D.D.S., Secretary of the Committee, New York City..... xviii

The Committee announces that the ordinance, passed by the Board of Aldermen of New York City and signed by Mayor Hylan, providing (as was announced on page cxlii of the section on *proceedings* in Volume I of the Journal of Dental Research) for an appropriation of $50,000 for the maintenance of nine additional free dental clinics in the public schools and for salaries for eighteen dental hygienists in these clinics, was recently reviewed by the Finance Committee of the Board of Estimate and Apportionment, and the action of the Aldermen, in effect, rescinded.—(W. J. G.)

Speed, efficiency, and painlessness, in tooth-cavity preparation. By J. Campbell Thompson, D.M.D., Boston, Mass..... xix

The author discusses an order of procedure in tooth-cavity preparation that is based on Black's classification of types of cavities and on Black's recommendations as to technique. Methods of effectively inducing anesthesia are reviewed. The author's conclusions (p. xxv) summarize his ideas and opinions, which he concentrates in the concluding remark that "speed, efficiency, and painlessness are most desirable to attain but the greatest of these is efficiency."—(W. J. G.)

"Prophylaxis." By Benjamin Tishler, D.M.D., Boston, Massachusetts xxix

A general discussion of the nature and importance of the Fones method of prophylactic procedure; and of the hygienic advantages accruing to the patient from the application of that treatment by the dentist.—(W. J. G.)

FUNDORS OF THE JOURNAL OF DENTAL RESEARCH

Names and Addresses of the Contributors to the Permanent Endowment Fund for the Support of this Journal, with a Financial Statement of the Amount and Status of the Fund, Compiled from the Eight Successive Reports in Volumes I and II of this Journal

This register, with the addditions to be made to it—a cumulative honor roll in dentistry—will be republished here annually as a recurrent testimonial to the generosity of those who, by their gifts to this Endowment Fund, will have established a permanent foundation for the unlimited growth and increasing usefulness of this Journal as an effective agent, in the public service, for the promotion of dental science, and the advancement of dentistry and stomatology.

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WILLIAM J. GIES.

Biochemical Laboratory of Columbia University,
Schools of Medicine and Dentistry,
437 West 59th Street, New York City,
December 15, 1920.

REVIEWS OF BOOKS RECEIVED FOR THE LIBRARY OF THE JOURNAL OF DENTAL RESEARCH

THE JOURNAL OF DENTAL RESEARCH promptly acknowledges in the "contents" section of each number, the receipt of new publications presented to it. Books selected from those received are reviewed in the "contents" section and are reprinted here. Reviews are matter-of-fact statements of the nature and contents of the publications referred to and are *intended solely to guide possible purchasers*. The wishes or expectations of publishers and donors of volumes will be disregarded, if and when they appear to be incompatible with our convictions regarding the interests of our readers.

The systematic development of x-ray plates and films. By LEHMAN WENDELL, B.S., D.D.S., Chief of the photographic work, and Instructor in Prosthetics and Orthodontia, College of Dentistry, University of Minnesota. 1919; pp. 78; 6⅝ x 4; $2.00. C. V. Mosby Company, St. Louis, Mo.

This little book is a very much needed and valuable contribution to the science of radiography. Probably more x-ray pictures are ruined during the process of development and fixing than in any other part of the technic, which is due principally to the fact that most operators discredit its importance because they lack adequate knowledge of the basic principles involved. The author has eliminated all extraneous matter, and has so ordered his consideration of the subjects that the busy practitioner is sure to appreciate the concise and comprehensive descriptions of the different methods, such as the visual, factorial and tank methods of development. The indications of ways of correcting over-developed or under-developed negatives add greatly to the value of the treatise. This book is one that every dentist should have in his library.—*F. T. Van Woert, School of Dentistry, Columbia University.*

General and dental pathology, with special reference to etiology and pathologic anatomy. By JULIO ENDELMAN, M.S., D.D.S., Professor of Special Dental Pathology, College of Dentistry, University of Southern California; and A. F. WAGNER, A.M., M.D., Professor of General Pathology, College of Dentistry, University of Southern California; Pathologist and Autopsy Surgeon of the County and City of Los Angeles. 1920; pp. 593; 6⅝ x 4⅛; $5.50. C. V. Mosby Company, St. Louis, Mo.

This treatise consists of two sections. The first section is an introductory survey of general pathology; the second, comprising about three-fifths of the book, is a more detailed consideration of disease processes as they affect the teeth and parts adjacent. The general section was written by Professor A. F. Wagner; the special, by Professor Julio Endelman—both of the University of Southern California.

Association of the scholar in medicine with the scholar in dentistry, both working toward a common end, like the coöperation of general and dental surgeons in military medical work, the institution of dental service in schools as a public-health measure, and the growth of dental departments for diagnosis and treatment in general hospitals, is worthy of comment as being a sign of the times. Indeed, the publication of a dental text-book on pathology alone is in itself a step in evolution. The earlier dental treatises combined in one volume all the special knowledge which the student was expected to acquire. As the fields of dental interest have developed, successive specialized text-books treating of them have appeared. The present is the first book, that ignores the application of therapeutics and treatment to its data, which has appeared in the field of dental pathology. Perhaps this, in future editions, may be able to presuppose more information on the part of its readers, and omit the chapters on normal dental histology and development, which are certainly adequately treated in numerous accessible hand-books.

The introductory survey of general pathology by Professor Wagner covers this broad field very satisfactorily. He discusses the chemistry, physics, and physiology of the cell in an opening chapter, which might perhaps have been omitted where space limitations necessitated such careful selection and rigid condensation. Etiology of diseases, pathologic processes, circulatory changes, inflammation, progressive tissue changes, tumors, infectious diseases, and malformations, are treated in the sequence indicated. Throughout the book an effort has been made to avoid reference to speculative discussions and to confine statements to proved facts. In the section on suppurations, however, the Streptococcus rheumaticus is referred to as apparently the chief exciting cause of rheumatic arthritis. The validity of Streptococcus rheumaticus as a species, or the extent of its rôle as an etiologic agent, are matters not yet by any means universally accepted. McCallum, in the latest edition of his text-book of pathology, refers to the "unknown infectious agent in rheumatism." Streptococcus erysipelatous, referred to in the same section, has been not only questioned as a separate species, but definitely discarded as such, and reference to it could well be deleted from a text-book of this character. Under the chapter heading of "infectious diseases" an excellent résumé is given of this group. Students of dentistry sadly need such teaching, to enable them to appreciate the growing literature connecting their field with the diseases of the body in general. Professor Wagner's brief description of Vincent's angina might well have been expanded in a treatise intended for dental students. No mention is made of the occurrence of this disease in the gingival region, although this is probably its most frequent initial site. The specificity of the fuso-spirillary organism is stated, but is not as definitely established a fact as the text would imply. Spirochetae thrive in necrotic tissue, and their causative relation to it in this disease, while probable, is not yet a matter for unqualified assertion. The statement that Bacillus fusiformis is an early stage of Spirocheta vin-

centi is not warranted. The spiral forms observed by Tunnicliff in older cultures of Bacillus fusiformis were doubtless involution forms of the bacillus, and the two organisms are now considered distinct species.

Professor Endelman's section of the book has introductory chapters on the normal histological characters of the dental and oral tissues, followed by detailed consideration of the etiology and pathological anatomy of the various deviations from that normal. In the chapter on hyperplasia, the term "atrophy" as applied by Black in his "Operative Dentistry," to this class of abnormalities, has been discarded for the less ambiguous "hypoplasia." In an article written a few weeks before his death, Black employed the term "dystrophy" (previously used by Cavallaro) for the defects dealt with in this chapter, which seems to be a better word than "hypoplasia." It, with "atrophy," used in its commoner sense of retrogression after attainment of the normal, and "hypertrophy," meaning overgrowth from the normal, form a logical series of terms for describing deviations in structure, size, and form. The condition known as "mottled teeth," with its interesting geographic distribution, might have received more attention, and more marked cases of discoloration selected for illustration than those portrayed in figures 123 and 124.

The chapter giving a résumé of the work of Cavallaro, on "Hutchinson's teeth and other syphilitic stigmata," deals with a subject of considerable importance, especially to those working in children's clinics, as it may lead to the detection and treatment of hitherto undiagnosed specific diseases, and the acquisition of further data greatly to be desired. Whether or not the opinion of Cavallaro, that "Hutchinson's teeth" are pathognomonic of hereditary syphilis in at least 50 per cent of the cases, is wholly tenable, it is unquestionable that hereditary syphilis does cause this type of dental dystrophy in a large proportion of cases. There is, however, much evidence to show that nutritional disturbances, and the exanthemata during late uterine and early extra-uterine life, play an important rôle. The Wassermann test has proved positive in 90 per cent of a series of cases of known congenital syphilis, and the subjection of a large series of cases with "Hutchinson's teeth" to this test might yield useful data. There are no published studies bearing on this point so far as the writer is aware.

The subject of dental caries is treated in five chapters, presenting the historical development of theories, general considerations as to influence of race and civilization's predisposing causes, pathological processes involved, and patho-histological studies of caries of enamel, dentine and cementum. Necessarily, in presenting a subject which is still obscure as to so many of its factors, there is a good deal of tentative statement. The various opinions as to the nature and importance of the gelatinous plaque are stated without a personal judgment as to their validity on the part of the author. In dealing with the bacterial factor in caries, the work of Kligler on "acid-producers" is quoted, but no reference is made to the insistence by Hartzell on the importance of the Gram-positive cocci in this process.

Mention is made, in the chapter on hypercementosis, of root-fillings

projecting beyond the apical foramen as a cause of this form of dental hypertrophy. It would be of interest to examine a series of radiographs of encapsulated root apices, taken at intervals, for evidence on this point.

In the discussion of chronic dento-alveolar abscess, the author objects to the term "granuloma" on the ground that the lesion is not a new growth, as implied by the termination "oma," nor is granulation tissue a characteristic of its contents. Moreover, he affirms that, until its adoption by a group of dental writers, it was applied to tissue-reactions occurring in response to certain bacterial and protozoan irritants, resulting in an infected mass of mononuclear wandering cells surrounded by a fibrous wall, which, breaking down, gave rise by metastasis to similar developments elsewhere. He points out that metastasis from a dental abscess does not result in the formation of a similar abscess elsewhere, although metastasis does occur; and he adheres to the older, and certainly more unwieldy term, "sinusless chronic dento-alveolar abscess."

The treatment of the subject of pyorrhea alveolaris is along the older lines, and fails to give an ordered and rational idea of the pathology. The disease is described according to its causes, such as salivary calculi, sub-gingival deposits, systemic origin. A separate chapter considers pyorrhea alveolaris of gouty origin. Traumatic occlusion as a causative factor does not receive the attention it should.

In the chapter on "mouth infections and systemic disease," the author summarizes the earlier work leading to the present ideas on the subject and contributes notes on a series of cases from his own experience. These notes bear on the clinical rather than the pathological side of the cases, as does so much of the literature relating to focal infection. There is still need for much study of the relationship between the microörganisms found in chronic dental lesions and the various diseases thought to be due to infection from such chronic foci.

The book is well arranged and printed, and profusely illustrated, there being three hundred and forty original illustrations in the dental section.—*E. H. Raymond, Jr., School of Dentistry, Columbia University.*

Practical orthodontia. By MARTIN DEWEY, D.D.S., M.D., formerly Head of the Department and Associate Professor of Orthodontia, University of Iowa; formerly Professor of Dental Anatomy and Orthodontia, Kansas City Dental College; President of the Dewey School of Orthodontia. (*Fourth revised edition.*) 1919; pp. 532; 7 x 4½; $6.00. C. V. Mosby Company, St. Louis, Mo.

An accurate, progressive, and fully comprehensive description of orthodontics, for the beginner or the advanced orthodontist, characterizes Dr. Dewey's fourth edition of his work in practical orthodontia. The rapid advancement of the science of orthodontia forces the author continually to renew his editions in order that the practitioner may have access to the knowledge of all the newer phases of technical skill and theoretical research in this great specialty of dentistry. The concise and direct style of description characteristic of the author is used in the vivid portrayal of all the practical appliances employed

by the leading men of the profession today. A thoroughly up-to-date knowledge of orthodontics may be gained by a study of this fine addition to dental science. An immense amount of study, research, sacrifice and valuable time is therein represented, by the author as well as by the men who have so kindly helped Dr. Dewey to compile this valuable edition. The beautiful illustrations that are generously distributed throughout the entire book, tend to visualize every phase of the science of orthodontia.

Emphasis is laid especially on the causes and etiology of malocclusions, indicating the author's deep study of the underlying principles of orthodontia. He first describes thoroughly the importance of the inclined planes of the cusps of each tooth, and their influence on the placement and locking of the teeth, either in proper occlusion or in malocclusion. He aims first of all to have the practitioner thoroughly understand the normal relation of each plane; for this knowledge is essential to the recognition of malocclusion. Dr. Dewey does not allow one to rest there, but carries him on to the other forces which influence the positions of the teeth in their individual arches and also in the relation of the two arches to each other. A still deeper study and research is depicted in the fourth chapter, where he thoroughly describes the etiology of malocclusions. Too many men today consider orthodontia a thoroughly mechanical process of "straightening teeth," as the laity calls it. Until a study is made of the causes—inherited, congenital and acquired—an accurate diagnosis and prognosis of any case of malocclusions is impossible to give. In this phase a closer relationship between the dentist or orthodontist, and the rhinologist and the medical profession in general, is obviously necessary; and the sooner thorough coöperation between these closely allied professions is obtained, the greater will be the progress of both branches.

The loss of deciduous or permanent teeth as the cause of malocclusions cannot be too strongly emphasized. This topic is treated thoroughly by Dr. Dewey; as is also the close relationship between mouth-breathing, and infected adenoids and tonsils, in the causation of various types of malocclusions.

Chapter III may be especially commended for its new nomenclature of the various classes and types of malocclusions. While Dr. Angle's classification has been universally used by orthodontists, it has been very confusing to the general practitioner interested in orthodontia, but who is unable to differentiate between a Class I, type 2, case and a Class II, division I, subdivision case. In this chapter Dr. Dewey recommends the use of the classification of malocclusions suggested by Dr. Lischer and adopted by the American Society of Orthodontists; and he uses this in conjunction with Dr. Angle's classification throughout his book. Thus, the three main classes are: *neutroclusion*—same as class I; *distoclusion*—same as class II; *mesioclusion*—same as class III. Each of these has its descriptive subdivisions to designate certain types of variation. Thus, in place of analyzing a case as "Class I, type 2," Dr. Dewey calls it a "neutroclusion with linguoversion of the maxillary anterior teeth." At once a vivid picture of the case is con-

veyed to the reader, whereas a numerical classification would not only be confusing but often entirely meaningless to one who is not familiar with that branch of dentistry.

Dr. Dewey classifies malocclusions, by the relation of the mandibular teeth to the maxillary in their respective arches, as Dr. Angle does. However, Dr. Dewey differs in his recognition of these classes in that he does not rely on the position of the molar teeth only, a general position of all the teeth, as well as the relation of the teeth to the general contour of the face, being his basis for diagnosis. Thus, a case may appear to be in distoclusion when as a fact the maxillary molars may have shifted forward (possibly from extraction of some adjacent tooth) and the case may really be a mutilated case of neutroclusion with a mesioversion of the maxillary molars. The classifications based on the mesio-distal or antero-posterior relation of the arches, whether bilateral or unilateral, are very vividly pictured by the use of curves or arches placed in different positions to each other and showing how the arches may diverge from normal relationships.

A very thorough description, and beautiful illustrations representing all types of malocclusions, form a sound basis for the reader to comprehend the meaning of malocclusion; and it is only with this knowledge that he can ably advise his patients in regard to orthodontic treatment.

A very large part of this edition is devoted to the treatment of cases by the use of various appliances. Dr. Dewey must be complimented on his cosmopolitan attitude toward various types of orthodontic devices. He does not recommend any particular type of appliance for the treatment of all cases, but rather recognizes the possibilities of many mechanical devices in different hands. Thus, he says, while one may get beautiful results with one appliance, that fact does not necessarily indicate the universal applicability of that appliance in such cases; for not only do the cases differ widely, but also the skill and experience of the orthodontists differ to a marked degree. Thus, one man may be successful with one appliance when another would entirely fail with it.

Much space is devoted to the use of the lingual wire in both the soldered form for wire-stretching as advocated by Dr. Lourie, and the removable lingual wire as used by Dr. Mershon. Both have their decided advantages and disadvantages, and all these points are very accurately described and emphasized by the author. The high-labial wire which is coming into wide use at present is also thoroughly described. While Dr. Dewey does not advise the use of lingual or high-labial appliances for the inexperienced operator, he depicts the wonderful advantages of such appliances in skilled hands and in certain cases. The technical skill of constructing such appliances is also an important factor in their utility. Warning is given the user of wire-stretching pliers used on a soldered lingual wire; and a very detailed description of the good movements, as well as the very undesirable movements possible to obtain, is presented. All types of appliances that are proving of value in practice today are given places in this edition, and an excellent knowledge of orthodontics may be gained by a study of this work.

In the seventh chapter Dr. Dewey treats one of the most important and most widely abused subjects of vital interest to the orthodontist, namely, anchorage and retention. More cases of orthodontia today fail because of a lack of knowledge or judgment in regard to the placement and reinforcement of anchorage than from any other cause. So thoroughly are these subjects treated in Dr. Dewey's book, that his mastery of his subject cannot for a moment be doubted. All means of anchorage and the reinforcement of anchorage are described, and all the forces of retention are very creditably analyzed.

It is impossible to do justice, in so short a review, to so wonderful a work as Dr. Dewey has contributed, since every chapter contains innumerable points of vital interest to the orthodontist and to all who may be interested in any way in orthodontia.

As a concluding word, I wish to emphasize the last chapter in the book, on nasal deformities in relation to malocclusions, on which subject Dr. Dewey has devoted a great deal of time and to whom we owe a great debt of gratitude for his untiring researches along the various lines pertaining to the theoretical knowledge of orthodontia as well as for the technical skill he has so ably developed.

A masterpiece—unselfishly, concisely and vividly portraying the study and practice of orthodontics to the practical orthodontist—is the justified description of Dr. Dewey's work.—*L. J. Porter, D.D.S., 17 E. 38th St., New York City.*

Everyday mouth hygiene. By JOSEPH HEAD, M.D., D.D.S., Dentist to the Jefferson Hospital, Philadelphia. 1920; pp. 67; 3¼ x 4¾; $1.00. W. B. Saunders Company, Philadelphia, Pa., and London, Eng.

To the professional man, Dr. Head's statement in his preface, that "cleanliness of the teeth and gums will absolutely prevent decay and may sometimes cure it," may seem a bit over-enthusiastic; but, on the other hand, it may be good to have the strength of one's belief so pronounced when he is writing for the laity. This little book was evidently intended primarily for the general public, to urge and stimulate that public to take better care of the teeth and gums. It is written in terms quite free from scientific nomenclature and couched in a language which will be understood by all.

After depicting in a concise way the ravages which follow the neglect of the teeth, the author takes up the means of properly cleansing the teeth. Dental floss is first considered; and the text is well illustrated with pictures that clearly help to demonstrate the proper handling and application of the floss. The tooth-brush follows. The rotary motion is advocated along with others, and reasons given for the use of a much smaller brush, especially as to bristle length, than is generally recommended. The dentist is urged not to forget "that each mouth is a separate problem and must be treated as such;" and that, where there are abnormal conditions, "the dentist must train the patient to see that these abnormalities are met and the parts are thoroughly cleansed by specially devised strokes of the brush." A few brief remarks on irregularity in children's teeth closes the book.

While dedicated to "loving mothers and conscientious nurses," and simply written for the public understanding, there is much in Dr. Head's book that the average dentist would do well to read, and not only ponder over but also put into practice.—*C. Franklin MacDonald, D.M.D., 180 W. 59th Street, New York City.*

An atlas of dental extractions, with notes on the causes and relief of dental pain. By C. EDWARD WALLIS, M.R.C.S., L.R.C.P., L.D.S., Dental Surgeon and Lecturer on Dental Surgery, King's College Hospital; Assistant Medical Officer (Public Health Dep't), London County Council; Late Dental Surgeon, Victoria Hospital for Children, Chelsea, etc. (*Second edition*, with eleven double-page plates.) 1919; pp. 26; 7 x 4⅛; $2.00. P. Blakiston's Son & Co., Philadelphia, Pa.

As the preface states, Dr. C. Edward Wallis' atlas is intended as a handy, simple, but reliable guide for the medical man, who, placed in a position removed from the services of a dentist, is called upon to relieve dental pain. The text is straightforward and quite unadorned with any theories or elaborate descriptions of dental conditions. In fact, the contents are presented in a really "popular" way, so that any layman, with ordinary medical knowledge, could carry out such procedures as are laid down quite well enough and with but slight difficulty.

The book is roughly divided into two main parts; the causes and relief of dental pain, and extraction. The first takes up the usual causes of pain in and about the teeth and gums; and, with a brief presentation of the salient symptoms, there are included a few suggestions of simple remedies which tend to relieve the condition. One possible source of dental pain, namely, the accumulation and impinging of large masses of tartar at the gum margin of a tooth, is hardly mentioned; yet it is a condition that is only too common but also easily corrected.

The anesthesia suggested for extraction is that of local injection of novocain. The whole procedure seems too vaguely presented. While the strength of novocain solution is not given, the warning not to use "the much advertised proprietary local anesthetics" is most happy.

The section devoted to extractions is interesting, and some very practical suggestions are offered for improvising dental chairs when none are available. The positions of patient, operator, and forceps upon the various teeth, are presented by means of full-page plates, which illustrate the situations very clearly. The lower forceps that the author pictures will, at first glance, be confusing to the average American-trained man, as they are markedly different from the forceps usually used in this country.

This compact little atlas will prove of great value to any medical practitioner so placed that, as on shipboard, with an expedition, or in certain remote country districts, he is liable to be called upon to relieve dental troubles. For the dentist who is not familiar with the so-called English forceps, the plates on extraction offer an excellent means of making the acquaintance of this type of forceps which, in many hands, prove most efficient in their application of force for the extraction of lower teeth.—*C. Franklin MacDonald, D.M.D., 180 West 59th Street, New York City.*

ERRORS AND CHANGES

Shortly after the distribution of the copies of each issue of this JOURNAL, we send to each author concerned a copy of his paper, or discussion, and of the corresponding "contents" abstract (taken from a finished copy of the number), with the request that a careful examination be made for the detection and formal correction of any errors that might have appeared. Special effort is made, by the editorial and publication offices, to prevent the occurrence of typographical and other errors, but, of course, occasional mistakes are inevitable. We desire, however, to correct errors, publicly and formally, when they occur, and to afford authors opportunity promptly to record revisions, in order that this JOURNAL may attain the highest possible realization of the ideal of perfect accuracy in every statement published on its pages.

We summarize, below, the only corrections and revisions that have been reported to us by the authors of the contents of No. 4 of Vol. I, and of Nos. 1, 2 and 3 of this volume.

VOLUME I, NO. 4

Proceedings: Charles E. Parkhurst, Editor

Page xcix; eighth line from the top. Martin B. "Dell" should be Martin B. *Dill.*

VOLUME II, NOS. 1, 2 AND 3

Paper by Arthur H. Merritt

Page 86, item 23. "Aveolaris" should be *alveolaris.*

Paper by William K. Gregory

Page 113. The end of the sentence on the last line should read: root while the *Dromotherium* molars have two *incompletely separated* roots.

Page 115. The sign indicating the relative size of *fig. 16* should be $\times 2$ instead of "$\times 1$."

Page 117; eleventh line from the bottom. "Monuse" should be *monus*.

Page 127; sixth line from the bottom: "known from a fragment of a lower jaw." *Note.*—Dr. W. D. Matthew, who has recently examined this fragment in the British Museum, has kindly given Dr. Gregory the following note: "This is a fragment of an *upper* jaw. It shows under binocular microscope three complete teeth which agree fairly well with the posterior molars of *Tritylodon*, and the roots or alveoli of three others in advance of them. It differs from *Tritylodon* in size, in the sharp incurvation of the maxilla a little above the teeth, and the more anterior position of the zygoma, if the above identification be correct, but may be provisionally referred to the same family."

Page 133; line 2: *Family* **Spalacotheriidæ**. *Note.*—After examining the specimens in the British Museum, Dr. W. D. Matthew has written as follows to Dr. Gregory: "It appears to me more probable that *Spalacotherium* is related to the Tituberculata in spite of the difference in the angle. The teeth are quite close to *Stylodon* and its allies, and of a type that appears to me fundamentally distinct from *Triconodon* and equally distinct from *Phascolotherium*."

Page 135. Part 1 of *fig. 24* shows the *inner* not the "outer" side of the left mandibular ramus; part 2 shows the *outer* not the "inner" side of the same.

Page 137; *fig. 26:* lower jaws of *Amblotherium*. *Note.*—Dr. W. D. Matthew notes that the jaws and teeth of *Amblotherium soricinum* are much like those of *Stylodon*, and that in the jaw of *A. mustelula* the teeth are poorly exposed and very much worn.

Page 139; *fig. 28:* lower jaws of *Stylodon*. *Note.*—Dr. W. D. Matthew, who has recently examined these specimens, has written to Dr. Gregory as follows: "These are imperfectly exposed. The tooth has in fact a trigonid with high protoconid, smaller but well developed inner cusps and a small-cusped talonid. They are Amphitheriidæ, differing from *Amphitherium* in the higher trigonid and smaller heel."

Page 142. Part *c* of *fig. 30* shows a *right* instead of a "left" lower molar.

Page 145; *fig. 33:* upper and lower molars of *Peralestes*. *Note.*—After examining the maxilla of *Peralestes longirostris*, Dr. W. D. Matthew notes: "The differences from the *Kurtodon* type are chiefly due to the presentation of the views. They are essentially the same, differing only in the presence of a distinct intermediate cusp on the postero-internal crest. This I take to be the upper dentition of *Spalacotherium*."

Thus, Dr. Matthew's *provisional* conclusions are: (1) that "*Spalacotherium*," the lower teeth, and "*Peralestes*," the upper teeth, belong to-

gether; (2) that both are allied with *Kurtodon;* (3) that both the stylodonts and spalacotheres are closely related to or derived from the older genus *Amphitherium*, but more specialized in the reduction of the talonid in the lower teeth; (4) that it is probable that *Spalacotherium* and the other Tritnberculata are fundamentally distinct from *Triconodon* and equally distinct from *Phascolotherium;* (5) that the main tips of the upper molar crowns of *Stylodon* and of *Peralestes* are serially homologous with the main tips of their premolars, and that they represent the para + metacones of Tertiary mammals; (6) that the Tritnberculata of the Mesozoic are paralleling the zalambdodonts of the Tertiary in the evolution of their molar teeth, and that (7) they therefore throw no new light on the ultimate origin of the tritubercular molar.

None of these conclusions is in conflict with the interpretation of the origin and evolution of the molar teeth adopted in Dr. Gregory's review. Dr. Matthew feels reasonably certain that the main tips of the upper molars in *Kurtodon* and *Dryolestes* are serially homologous with those of the premolars, as set forth in Parts I and II of Dr. Gregory's review.

Page 164; *fig. 41.* The upper part of the double illustration pertains to the beaver; the lower part, to the wombat.

Page 223. The legend for *fig. 44* should be completed by the addition of the following: *pr*, protocone; *pa*, paracone; *me*, metacone; *pr*^{d}, protoconid; *me*^{d}, metaconid; *hy*^{d}, hypoconid; *en*^{d}, entoconid.

Page 225; fourth line from the top. Insert, in parenthesis, *plate 5, figs. F* and *G.*

Page 226. The legend for *fig. 46* should be completed by the addition of *pa*, paracone; *me*, metacone; *pr*, protocone; *hy*, hypocone; *pr*^{d}, protoconid; *me*^{d}, metaconid; *hy*^{d}, hypoconid; *en*^{d}, entoconid,; *ms*^{d}, hypoconulid (mesoconid).

Page 228. Under the legend for *fig. 48* should be inserted the phrase: *After Granger.* In the second line from the bottom, the word "many" should be stricken out.

Page 230; legend for *fig. 49.* In the third line, the two words "Lemuri formes" should be one word.

Page 231; twelfth line from the bottom. The comma after "clear" should be removed.

Page 235. "*Fig. 50A*" should be designated simply as *fig. 50.* The teeth referred to in the legend are *upper* teeth. Dr. W. D. Matthew notes that the premolar of *Mixodectes* sp. is probably wrongly associated with the other teeth. In the legend for *fig. 51*, the teeth referred to are *upper* teeth.

Page 238; last line above the figure. *Parenthetical reference to plate 6* should be inserted.

Page 242; twelfth line from the bottom. The canines referred to were *lower* ones.

Page 250; last line. Parenthetical reference to *fig. 56* was omitted.

Page 261. End of the first paragraph: parenthetical reference to fig. *73* was omitted. End of the next to the last paragraph: parenthetical reference to *figs. 74* and *75* was omitted.

Page 272; end of the second paragraph. Parenthetical reference to *figs. 71* and *72* was omitted.

Page 394. Fifth line from the bottom: "*N. zitteli*" should read *N. antiquus* (*fig. 136*). Fourth line from the bottom: "*proto*conule" should have been substituted by *meta*conule.

Paper by Franklin W. McCormack

Page 492; *fig. 1*, item *Z*. The legend, "lower third molar: dark area around apices, probably from superimposition of the overlying muscular tissues," should read: *lower third molar: dark area distal to the tooth, probably due to superimposition of overlying muscular tissues in contrast with the triangular space between the dorsum of the tongue and the pharyngeal wall.*

Page 504; *fig. 53*. The phrase in the last line of the legend, "which appears to limit the canal inferiorly," should read: *which appears to limit the mass inferiorly.*

Proceedings: Discussion by George Evans, Sr.

Page xiii. The third sentence, "Heitzmann maintained that there is circulation not only in 'dead' teeth and in pericementum, but even in the enamel itself," should read: *Heitzmann maintained there was vitality in the cementum of pulpless teeth; and in vital teeth, circulation not only in the dentine but in the enamel itself.*

SCIENTIFIC PROCEEDINGS OF DENTAL AND STOMATOLOGICAL SOCIETIES

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AN EXPERIMENTAL STUDY, WITH CERTAIN "VITAL DYES," OF THE PERSISTENT TEETH OF THE ALBINO RAT

JOHN S. MARSHALL

Anatomical Laboratory of the University of California, Berkeley, California

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INTRODUCTION

Early in my connection with this laboratory I became interested in the special research conducted here, by Professor Herbert M. Evans, chief of the department, and his assistants, upon certain tissues and organs of the albino rat and other rodents by means of vital staining. As this seemed to offer an interesting and profitable field of study, and a possible means by which certain problems in the morphology and histology of the enamel and of other dental tissues could possibly be elucidated, I was induced by the advice and suggestion of Professor Evans to begin a series of studies upon the jaws and teeth of lower animals.

In beginning this study it was necessary to select a laboratory animal that would be always on hand and available for experimental purposes. The decision fell upon the albino rat—Mus norvegicus albinus—for the reason that it fulfilled these requirements, and also because it was possessed of continually growing teeth (incisors)

and reached full maturity in about one hundred days, thus making it possible to study the growth of the teeth, from a very early period of life to complete maturity, within a comparatively short period of time.

The morphology and histology of the teeth of all the mammalia bear a very close resemblance to each other—so close a resemblance as to make it possible, with very little chance of error, to apply the findings and conclusions deduced from studies upon the lower orders of the mammalia to the teeth of the higher orders of mammals up to the *genus homo*.

These particular studies have been pursued for the last three years. During that time I have prepared over one hundred and fifty jaws of rats with the teeth *in situ*, by the grinding method. My first work was done upon jaws and teeth that had been decalcified; but, so far as the teeth were concerned, this process was of little value for the study of enamel, since decalcification destroyed this tissue almost completely, and the acids employed for decalcification removed every vestige of the stain from the other tissues.

TEETH OF THE RAT

Formula: Incisors $\frac{1}{1}$ Cuspids $\frac{0}{0}$ Premolars $\frac{0}{0}$ Molars $\frac{3}{3}$

The rat has but one set of teeth, hence dentition is monophyodont. The whole period covered by the eruption of the teeth is from twenty-five to twenty-six days. The incisors are the first to make their appearance—on the eighth to the tenth day after birth. The first and second molars appear, respectively, on or about the nineteenth and twenty-first days after birth, while eruption of the third molars is usually delayed until about the thirty-fifth day. After the eruption of the second molars the animal is capable of maintaining an independent existence. The second molars are the largest teeth in that series. The incisor teeth belong to the class termed *persistent*, for they grow from a persistent pulp, and are without roots, though firmly set in a deep, strong alveolus. The incisor teeth grow constantly during the life of the animal, as do the tusks of the elephant.

The teeth of the rat, like those of other mammalia, are composed of three hard or calcified tissues, namely, enamel, dentine, and cementum; and of two soft or vascular tissues, namely, pulp and pericementum.

The enamel forms only upon the outer or labial aspect of the incisor teeth. In the molars, the enamel covers the entire crown of the tooth. The cementum and pericementum are formed upon the inner or lingual aspect and sides of the incisor teeth. The roots of the molars, however, are completely invested with cementum and pericementum, and surrounded by a strong and definite alveolar process.

The sulci of the morsal or grinding surfaces of the molar teeth appear to be filled with a form of cementum, which wears away more rapidly than the enamel and thus tends to keep the morsal suffaces in good condition for grinding and triturating the food. The morsal or grinding surfaces of the molar teeth are all upon the same plane.

The lower jaw or mandible is formed in separate halves, bound together on the median line by a strong ligament. There is no bony union between them. The animal has the power of advancing the lower jaw, so that the inferior incisors can be closed upon the outside of the superior ones. Enamel being formed only upon the labial aspect of the incisor teeth, these teeth in both jaws are constantly worn to a chisel edge. The incisors and molars of both jaws are separated from each other by a wide interval or *diastema*.

The incisor teeth are much curved, the superior teeth curving downward, and the inferior ones upward. Owen (7) describes "the curve of the lower as being a smaller segment of a larger circle, and of the upper as a larger segment of a smaller circle." Owen also states that "the abrasion resulting from this reciprocal action of the upper and the lower incisors produces accordingly an oblique surface, sloping from a sharp anterior margin formed by the dense enamel, like that which slopes from the sharp edge formed by the plate of hard steel laid upon the back of a chisel, whence the name given to these teeth, *dentes scalprarii*. These teeth are the longest incisors and usually have their alveoli extended below, or on the inner side, of those of the molars to the back part of the lower jaw." According

to Donaldson (1) the segment of the circle, in the adult animal, is from 140° to 145°.

The writer finds that the lower incisors have also a slight lateral (inward) curvature of from 5° to 8°, which makes it very difficult to grind these teeth so as to obtain a complete parallel section for their entire length.

The growth of the incisor teeth of the rat, as determined by Donaldson (1), is, for the superior, an average of 2.2 mm. per week; for the inferior, 2.8 mm. per week. In a normal occlusion of the incisor teeth the wear is equal to the growth; but when they fail to occlude in a normal manner, and no wear takes place, these teeth grow to great length, curving towards the head, and sometimes penetrating the skull and killing the animal. At other times the incisors are diverted to one side or the other of the head and, by their lateral pressure, throw the jaws out of aligment, thus obstructing the movements of the mandible, preventing occlusion of the molar teeth and therefore of mastication, and ending the life of the animal sooner or later, by starvation.

The incisor teeth of the rat were chosen for this study, for the reasons already stated, namely, that these teeth grow continuously during the life of the animal; they have no roots, but grow from persistent pulps (*fig. 1*); and consequently the cells concerned in the formation and development of the various structures of the tooth can be studied from the earliest period of their formation to their complete development. This appeared to be a very great advantage over the study of these structures in some of the larger orders of the mammalia, like the lamb, pig, cat or dog, or the human embryo, on account of the difficulties encountered in obtaining embryos of many of these animals at desired periods of development, and the even greater embarrassments involved in securing human embryos in sufficient numbers and at selected periods of development. The selection of the incisor teeth of the rat offered the further great advantage of a predetermined preparation (by vital staining) of the tissues for study during the life of the animal. The human embryo can rarely be secured for research purposes until the vitality of its cellular elements has entirely disappeared. Consequently, the staining of such tissue was very unsatisfactory for the purposes of this investigation.

Devitalized tissue cells are prone to stain *en masse* (2), while living cells (embryonic cells) generally show the stain in granular (punctate) form. This is particularly noticeable in the living macrophages and fibroblasts of the connective tissues, and in the ameloblasts of the enamel.

Healthy animals only—generally such as were young and growing—were used in this work.

VITAL STAINING AS A METHOD

By the term "*vital* staining" is understood the staining or dyeing of the tissues of a *living* animal by injection of certain stains or dyes not harmful to health nor destructive of life. In my own experiments, in this relation, the dyes were injected intraabdominally. A sterile aqueous solution of the dye was always employed, and injection always done under strict aseptic precautions. The relative non-toxicity of such dyes has been shown by their satisfactory use in innumerable experiments upon the lower animals. The dye, when injected into the abdominal cavity, is absorbed into the blood very rapidly and is promptly disseminated over the whole body in the circulation, and from it through the blood-vessels. The skin and the oral mucous membrane show the stain in a few hours. Since the dye is absorbed from its place of injection and distributed throughout the body by means of the vascular system, from which it again escapes into the tissues, it is evident that vital staining appears earliest just outside the blood vessels and is always exhibited most intensely in such locations.

A rat stained with violet, purple or blue dye shows the stain in the incisor teeth, both superior and inferior, at the central portion, directly over the pulp-chamber, in two or three days after injection (*figs. 2, 2a, 2b*).

This method of staining has opened, to the dental morphologist and histologist, an entirely new and most interesting field of study and research, by reason of the fact that certain acid vital dyes (azo-dyes) have a marked predilection for, and almost a specific tendency to lodge in, certain cells and tissues during the embryonic stage of their development.

Vital staining, as applied to the study of dental morphology and histology, is a subject of intense interest. Heretofore the investigator has been dependent upon the old methods of staining—staining of formed and dead tissue. With this new method of vital staining, the tissues are prepared for investigation while in their embryonic stage and during their growth in the living animal. This makes it possible, of course, with the incisor teeth of the rat, growing as they do from a persistent pulp, to study the tissues, particularly the enamel and the dentine, from their earliest beginnings to complete development.

VITAL STAINING OF THE TEETH OF THE RAT

Enamel

The enamel organ is an epithelial structure derived from the epithelial layer of the embryonic oral mucous membrane. The enamel cells (ameloblasts) are modified columnar epithelial cells. The enamel organ in the rat appears to be a double membrane, the parts being separated by a more or less regular open space. I have, however, been unable to demonstrate, to my entire satisfaction, the occurrence of a stellate reticulum, although this is a simple matter in the developing tooth of such animals as the lamb and pig.

The outer tunic of this double-appearing membrane is supplied with blood from the alveolar bone, as may be readily observed at the base of the developing incisors, from the presence there of numerous capillary blood-vessels and many deeply stained macrophages and fibroblasts. The inner tunic is also supplied with a capillary circulation, as may be readily demonstrated by killing a rat and immediately injecting the animal through the aorta with a solution of *India ink*, removing the mandible, decalcifying it, imbedding it in celloidin, and cutting sections 15 to 20 microns thick. The ameloblasts lie next to the inner tunic and the alveolar bone lies next to the outer tunic, with a thin fibrous membrane between, presumably periosteum.

It has been observed by Professor Evans, in experiments in this laboratory with the acid vital-dyes, that epithelial tissues as a rule do not take these stains. The epithelial structures of the alimentary

tract, from mouth to anus, it is generally stated, do not take the stain of any of the acid vital dyes. Neither are the epithelial structures of the skin, lungs, salivary glands or pancreas affected by them. On the other hand, the epithelial elements of the liver and kidneys are intensely stained (2). The connective tissue structures, like skin, bone, periosteum, pericementum and the dental pulp, take the stain very readily and store it for a considerable period. In one of our cases stained with trypan blue, the stain persisted for more than a year, the skin still being markedly blue and, at autopsy, the structures of the jaws and teeth showing quite intense staining.

In some of my specimens the ameloblasts and the secreting papillae of Williams contain numerous round glistening bodies; and there is *punctate* staining in the embryonic enamel rods, when either a violet, purple or blue dye is used, as may be seen when the tissue is cut in longitudinal or transverse section.

The enamel rods in longitudinal section, as seen at the base of the persistent pulp (with oc. no. 4, obj. $\frac{1}{12}$, oil immersion), appear first to be soft fibrils which take the stain rather faintly; later they assume the form of tiny globular masses, piled one upon another in a regular order, with narrow intervals between them and forming into strings or columns. These globular masses look very much like the rouleaux formed by the red blood-corpuscles in the process of blood coagulation. They appear to be formed with thick rims (biscuit-shaped) like the red blood-corpuscles. In the earlier stages of their formation, this biscuit-shape is clearly marked; later they seem to settle together and leave only a faint trace of their union, which gives the striated appearance to the enamel rods.

The enamel rods appear to be about twice as wide as the interprismatic substance that separates them. In transverse section the enamel rods, under the power indicated above, appear to be irregularly hexagonal, five- or six-sided. Under a lower power they appear to be circular. The rods show *punctate* or granular staining when in focus (*fig. 3*). ***The interprismatic substance shows no staining at all.*** When out of focus, the stained enamel rods appear to be colorless, and the interprismatic substance has a faintly darkened outline.

It may be interesting, in this connection, to note in detail the treatment of Rat "L²" (No. 204, Dr. Long's series), from the enamel

of which *fig. 3* was drawn, and also the method of preparing the tissues for, and the results of, microscopic examination. The area shown in the illustration (*fig. 3*) was taken from the forming enamel near the base of the *persistent* pulp, and shows a section of enamel and dentine with punctate staining in the enamel rods and in some of the dentinal tubuli.

History. Rat "L²" (Rat 204). Animal injected by Dr. Long. *Born, October 19, 1916.* Dianil blue (Dianilblau RR), 1 per cent solution, injected intraperitoneally.

DATE AND TIME OF INJECTION 1916	VOLUME INJECTED	DATE AND TIME OF INJECTION 1916	VOLUME INJECTED
	cc.		*cc.*
Oct. 22 9:30 p.m.	0.1	Nov. 3 2:00 p.m.	1.0
24 1:00 p.m.	0.2	6 2:30 p.m.	1.0
26 12:00 m.	0.2	7 2:00 p.m.	1.0
28 12:00 m.	0.2	8 1:20 p.m.	1.0
30 3:00 p.m.	0.2	9 2:00 p.m.	1.0
Nov. 1 3:40 p.m.	0.5		

November 11, 1916, killed with chloroform; head immediately severed from the body and placed in 10 per cent solution of formol and in a thermostat at 35°C. November 22 it was transferred from formol solution to 95 per cent alcohol; December 7, to absolute alcohol; December 8, to Canada balsam (xylol balsam) for impregnation. On January 4, 1917, after twelve hours of hand-grinding, the specimen was cleared in absolute alcohol and xylol, and mounted in xylol-balsam.

Microscopic examination. (*At the base of the tooth pulp.*) The forming enamel rods show staining with dianil blue. The dentin is slightly stained. The enamel is deeply stained. The rods are stained. *The interprismatic substance is not stained.* Some rods show deep staining at the central portion, others have granular or punctate staining. At the junction of the dentine and enamel there is a considerable accumulation of blue granules while, at the outer periphery of the enamel, the embryonic tissue is still more deeply stained. The pulp is deeply stained blue, showing many stained macrophages and fibroblasts. The alveolar bone and also the blood-vessels are deeply stained blue. The pulps of the molar teeth and the pulp of a developing third molar show deep staining, as does also its bony crypt. Blue granules can occasionally be found in the dentinal tubuli in the early stages of the formation of the dentine. The pulp of the

incisor is most deeply stained at the morsal apex. The stain has seemingly accumulated at this point.

The stain, which always appears (in the vitally stained animals) as a granular detritus, seems to be arrested at the pulpal surface of the dentine. Numerous small granules appear in the odontoblasts.

Transverse sections of the enamel rods show deep staining. The stain is deposited in the form of minute granules but unevenly distributed. Some rods have the granules evenly deposited in them. Others have the deposit seemingly in the center only; in others the granules appear to be deposited at one side. (This appearance is probably due to the angle at which the rods are sectioned.) The *interprismatic* substance is not at all stained.

Certain faint lines appear in the dentine of the incisors following the long axis of the tooth at uneven distances apart, beginning at the basal end of the tooth and fading out as they approach the occlusal end. These lines (double), five in number, look something like the lines of Schreger, or the incremental lines of Owen. After careful comparison it was determined they were not incremental lines.

Enamel rods in longitudinal section are seen to be made up of little biscuit-shaped disks or globules piled one upon another. Enamel rods in transverse section (seen under oc. no. 4, obj. $1\frac{1}{2}$, oil immersion) appear to be hexagonal, five- or six-sided. They have taken the stain and have a granular or punctate appearance. The interprismatic substance *is not stained*. When out of focus the enamel rods appear to be colorless and the interprismatic substance has a faintly darkened outline. The color in the enamel rods fades out as the morsal or cutting end of the tooth is reached, and finally disappears entirely. The mature dentine does not appear to be stained—the stain has evidently faded out. The pulp and the forming enamel are usually highly stained. Wherever blood-vessels abound the stain is in evidence.

As the enamel rods grow older, and the tissue in its growth moves towards the morsal or cutting edge of the tooth, the stain fades out, so that by the time the location of wear is reached, the stain has entirely disappeared.

The enamel rods in the teeth of animals vitally stained with violet, purple or blue dye always show a *punctate* or granular form of staining when seen in transverse section with the higher powers of the microscope. The studies of Professor Evans and Dr. Scott (3, 4) in this

laboratory have demonstrated that the "vital granules" of these dyes are in reality small storage vacuoles produced by the living cells. The *punctate* or granular staining of the embryonic enamel rods is therefore evidence that the protoplasm of these rods was living at the time of the deposition of the rods, and that, after storing a certain amount of the vital dye, the protoplasm later gave up the stain as the enamel tissue was matured.

Another condition worthy of notice is the fact that the enamel of the incisor of the rat, or rather that portion exposed to the fluids of the mouth, has usually, under normal conditions, a strongly marked yellow tint, which becomes deepest at the morsal or cutting edge. To attempt to assign a reason for this condition would be at best only a matter of speculation, for it may be due to the greater density of the mature tissue, to exposure to the action of the salivary fluids, or to stains from the food, etc. Not all of the rats, however, show the same deep yellow stain of the enamel, but all are more or less tainted with it.

Fully developed enamel is formed only upon the labial or anterior aspect of the tooth. The enamel is quite thick upon the labial surface and ends laterally in thick, abrupt margins. At this point the cementum, which is very thin, is overlapped at the cervical margin by the enamel.

The dentinal tubuli break up at the dento-enamel junction into numerous fine branches, and seem to end in a granular layer, the granular layer of Tomes. The dento-enamel junction is well marked. Beyond this junction may be seen (oc. no. 4, obj. $\frac{1}{12}$, oil immersion) numerous "ampullae" in the enamel, of various sizes and length, with processes passing outward between the enamel rods, to be lost in the interprismatic substance. I have been able *positively* to demonstrate the presence of color (stain) in the dentinal tubuli, but not in the "ampullae" of the enamel, of the teeth of vitally stained animals. In some localities, however, it has seemed to be present. The "ampullae" at the dento-enamel junction of the rat are more inclined to end in olive-shaped terminations than in fine fibrillae. This appearance may be due to the limited power of the objective ($\frac{1}{12}$, oil immersion).

The "ampullae" are most numerous at the lateral terminations of the enamel, and many of the ultimate branches of the dentinal tubuli cross the dento-enamel junction to be lost either in the prismatic substance, or the "ampullae."

The enamel rods are arranged (as in human teeth) in a direction, usually, perpendicular to the surface of the dentine, and present the same striated appearance. In the incisors, however, the enamel rods have a morsal inclination.

I have been unable positively to demonstrate an enamel cuticle, Nasmyth's membrane; but the presence of certain structures covering the enamel in young teeth, leads me to believe that these structures constitute an enamel cuticle.

Four conditions are very noticeable in the completed, mature, structure of the enamel of the rat.

(1). The rods or prisms are laid down in very regular rows, with an inclination in the incisors towards the morsal or cutting edge.

(2). The rods are relatively twice as wide as the interprismatic substance that separates them (oc. no. 4, obj. $\frac{1}{12}$, oil immersion).

(3). The rods are built up of biscuit-shaped globules, arranged with the greatest precision.

(4). The rods take the stain in the early stage of their development, the color later fading out; but the interprismatic substance never takes the stain at all.

Dentine

The dentine, which forms the great bulk of the tooth, is a connective-tissue structure, harder than bone and less dense than enamel. As a connective-tissue structure, it is capable of receiving the color of a vital dye.

The dentine-forming cells (odontoblasts) with their processes, form a complete membrane-like outer covering to the dental pulp. These cells, with the pulp, also take the stain very readily. There is undeniable evidence that occasionally the dentinal tubuli in vitally stained animals receive the stain and possibly transmit it. The pulp tissue and the odontoblasts, however, in all probability, constitute a filtering mechanism that retains nearly all the available dye as the stain leaves the pulp capillaries. We know that wherever there is a blood-

circulation in a tooth the dye will penetrate, and that all connective-tissue cell elements supplied with nutrition by such circulating fluid receive the stain.

Injections with the violet, purple and blue dyes show plainly in the dentine, by leaving certain colored lines, which apparently correspond with the number of injections made, and the intervals between them. These lines when first produced lie next to the pulp and are therefore formed while the dentinal tissue is in the embryonic stage. They, however, soon fade out, and leave the dentine without any evidence of having been stained by the time this portion of the dentine (in its natural growth) reaches the morsal or cutting edge of the tooth. In a later communication I intend to discuss this subject at length. It is worthy of note, however, in this connection, that, in some of my earlier studies with these same dyes, human adult teeth, stained through the apical foramina *in vacuo*, showed that the dyes had penetrated the dentinal tubuli and lodged in certain "ampullae" found at the dento-enamel junction (5) and in "Tomes' granular layer" (6). Consequently, the general lack of vital stain in the dentinal tubuli when azo-dyes are administered, can not be taken to indicate the absence of a fluid passage into these tubuli from the pulp.

The dentine at the base of the pulp, where it is in its embryonic stage of development, shows the stain quite strongly, but only occasionally have I been able to observe any color in the dentinal tubuli.

As the tooth wears away at the morsal or cutting edge of the incisors, the pulp-chamber is closed with new material, *probably a vaso-dentine*, for the stain in the pulp shows through at this point (*fig. 2b*).

The "granular layer of Tomes" is well marked at the dento-cemental junction, many of the dentinal tubuli terminating in "ampullae" and lacunae-like spaces, ***but leaving a clear space between that layer and the cementum.***

Cementum

The cementum is also a calcified connective-tissue structure, harder than bone, but less dense than dentine. It closely resembles the compact tissue of bone, but has fewer lacunae and no Haversian systems. In specimens of human hypercementosis, the lacunae are numerous and occasionally Haversian systems are present.

The cementum in the rat is comparatively thin and covers the dentine of the roots of the molars from the cervix to the apex, being thickest at the latter location. In the incisors, it is formed only upon the lingual side of the tooth; or, in other words, upon that surface in the superior which faces the tongue and in the inferior that which faces the palate.

The cementum in all my specimens contains numerous oval cells (unstained), probably cementoblasts, and shows also a rather uniform, faint, diffuse staining, thus proving conclusively that the color is brought to it by the blood-vessels of the pericementum and not through the dentinal tubuli from the pulp. No evidence of stain can be seen as passing though the dentinal tubuli to the cementum. (In all my studies of the rat, it has never been my fortune to find any abnormal tissue.)

The cementum does not die or become necrosed in man upon the death of the pulp, for its vitality is dependent alone upon the presence of a living, functioning pericementum. The cementum of the rat is quite thin in comparison with the pericementum. I have been unable to distinguish with certainty any lacunae in the former tissue.

Pulp

The pulp is a highly vascular connective-tissue organ, presumably abundantly supplied or endowed as in the human subject, with blood-vessels, nerves and possibly lymphatic vessels. Further research will be necessary to establish the latter presumption.

The pulp occupies the central cavity or pulp-chamber of the tooth, and gives nourishment and sensation to the dentine and possibly to the enamel. Should the pulp lose its vitality by disease or traumatism, the dentine and enamel would be cut off from all nutrition and sensation and thus become practically dead tissue.

In injected rats the pulp is always deeply stained with the dye employed, as are also the odontoblasts. The pulp-stain is due entirely to vitally stained macrophages that are resident in the connective tissue in the pulp. *Fig. 4* is a longitudinal section of the incisor tooth of an adult mouse that had been vitally stained with dianil blue.

The incisor teeth sometimes become broken off down to the gingivae. I have carefully examined several cases of this character, but in no instance was the pulp exposed, nor could I discover any evidence of irritation due to the traumatism. A further study of the pulp is reserved for a future communication.

Pericementum

The pericementum is a fibrous connective-tissue structure analogous to the periosteum of bone. It covers the entire outer surface of the cementum, and is supplied with blood-vessels and probably with nerves from the alveolar bone.

The pericementum takes the stain of the azo-dyes more deeply than does the cementum, on account of its vascularity. The membrane appears to be about twice the thickness of the cementum, while at the apices of the roots of the molars it is much thicker. Stained macrophages and fibroblasts are very numerous in it. Under the higher powers of the microscope (oc. no. 4, obj. $\frac{1}{12}$, oil immersion) many fibers can be seen to pass through it from the alveolar bone to the cementum.

The junction between the dentine and the cementum is well marked and usually shows a clear space between the "granular layer of Tomes" and the cementum. The areolar spaces are larger and more numerous next to the alveolar bone. The fibers break up into tufts and spread out laterally into a delicate network, and are attached to the surface of the cementum.

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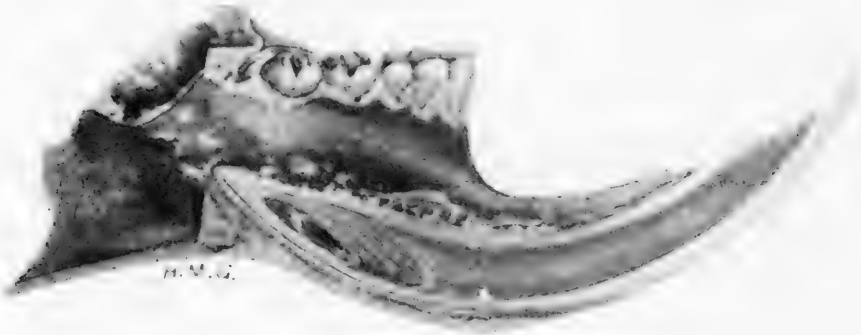
PLATES

PLATE 1

FIG. 1. Longitudinal section of the lower jaw of an adult rat. Incisor tooth (in situ) vitally stained with dianil blue. (× 5)

FIGS. 2 AND 2a. Upper jaw of an adult rat. Incisor teeth (in situ) showing (vital) stain (dianil blue) over the pulp-chamber. Figure 2a shows a lateral view of the stained incisor. (× 4)

FIG. 2b. Upper incisor teeth of an adult rat stained vitally with trypan blue, showing stain in the vaso-dentine. (× 6)



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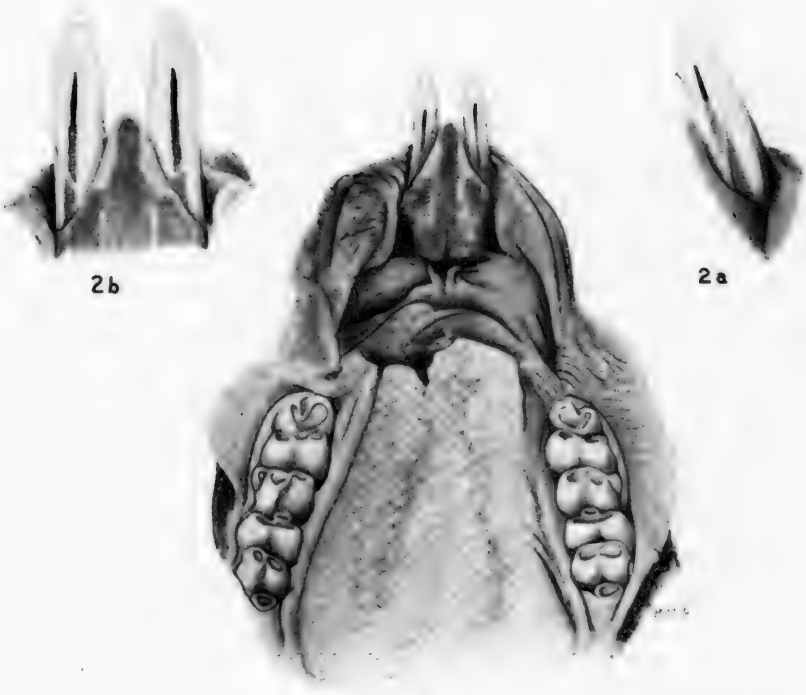


2b 2a

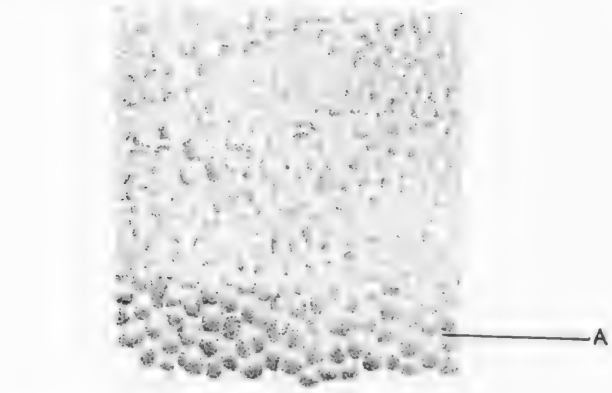
2

(Marshall: Vital Staining of Teeth)

PLATE 2

FIG. 3. Enamel rods of a rat tooth (transverse section), vitally stained with dianil blue. *A*, punctate staining; *B*, dentinal tubules. Units (8) on the scale: each, 0.01 mm.

FIG. 4. Longitudinal section of a lower incisor tooth of an adult mouse vitally stained with dianil blue. *AP*, apex of pulp; *B*, bone (alveolar); *C*, cementum; *D*, dentine; *E*, enamel; *M*, muscle; *P*, pericementum. (× 6)



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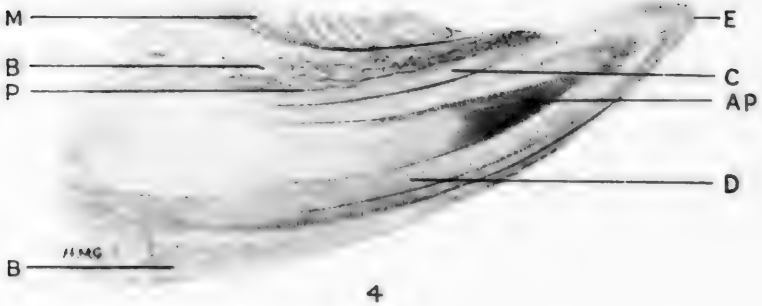

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(Marshall: Vital Staining of Teeth)

THE DISINFECTION OF THE ORAL MUCOSA WITH CRYSTAL VIOLET AND BRILLIANT GREEN[1]

C. COLEMAN BERWICK

George William Hooper Foundation for Medical Research and Research Laboratories of the Dental Department of the University of California, San Francisco, California

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[1] According to Churchman (*Journal of the American Medical Association*, January 17, 1920), the term "disinfection" when applied to the action of dyes, is a misnomer. He prefers the term "*bacteriostasis*," not only from an etymological point of view, but also from the standpoint of accuracy of description. We believe, with Churchman, that the term "bacteriostasis" is a more suitable one than "disinfection," in this relation.

I. INTRODUCTION

In the study of the bacteriology of apical and periapical infections, there is great variation in the cultural technique of different investigators. Since the relative value of the results obtained by different experimenters depends upon an unbroken chain of aseptic procedures in each case, it is important to ascertain what technical conditions must be established for the sterilization of the oral mucosa, and also to determine the relative efficiency for this purpose of the available antiseptics. From a consideration of some of the many methods used to obtain material for bacteriological study, especially material in the vicinity of the gingival border, it is apparent that the technique described is not free from criticism. To such an extent does this fact obtain that opinions, rather than scientific facts, appear to have influenced, if not actually to have served as a foundation for, the results reported.

Gilmer and Moody (7) state that "the field to be incised was made as nearly aseptic as possible by thorough washing with 50 per cent alcohol." Schamberg (21) says: "We removed the tooth and from it got a pure culture of Streptococcus viridans." Hartzell and Henrici (10) state that it is "almost an impossibility to extract a healthy tooth and find it free from viridans unless that tooth has been rendered free from bacteria by rubbing the tooth with iodine and subsequently burning the gingival field with the actual cautery." Head and Roos (11) "washed the neck of the tooth with alcohol until it was considered to be practically free from living bacteria. It was then painted with tincture of iodine three times at short intervals so that it would be practically impossible for any organisms on the neck of the tooth to be alive." Howe (12) uses two solutions: (a) silver nitrate, 3 gm.; distilled water, 1 cc.; ammonium hydroxid (28 per cent), 2.5 cc. and (b) formalin (25 per cent). These two solutions, mixed, make everything absolutely sterile, according to Howe, and destroy every type of microörganism. Rosenow (20) does not give any technique for obtaining his material but states that the danger of contamination, with the mouth flora, in the removal of teeth, "becomes slight in proper hands."

Kelsey (13) tested a great variety of substances in the culture of organisms to ascertain their value as disinfectants. He concluded that "tincture of iodine is the most useful disinfectant for use in the mouth in treating lesions where strepto-bacillus is present." Kelsey gives no clinical evidence with the results of his laboratory work, but assumes that his laboratory findings apply in vivo as well as in vitro.

II. THE GENERAL PLAN, METHOD, AND RESULTS OF THE AUTHOR'S EXPERIMENTS

In view of the uncertainty revealed by these quoted statements, we sought to find an antiseptic which would be efficient and yet which would be relatively innocuous to the normally sensitive mucous membrane of the oral cavity. In the light of the suggestion by Meyer (19), the problem was attacked from a chemotherapeutic view-point. Accordingly, observations were made upon the therapeutic and chemical effects produced by various drugs ordinarily used in clinical practice, as well as upon suggested changes in concentration of the antiseptics. The mode of application was the same in all instances, namely, by means of cotton pellets moistened with the different fluids. Application was always made on the gum of the maxilla near the frenum.

1. First series. Results with alcohol, acetone, ether, and tincture of iodine

The results obtained with alcohol, acetone, ether, tincture of iodine, and *dilute* tincture of iodine, are summarized in *table 1*. It will be noted that, in the use of either 60 per cent alcohol or 95 per cent alcohol, there was variation in the degree of dehydration of the gum. When the application of alcohol was followed, in turn, first by ether, second by acetone, finally by a mixture of the three in equal proportions, the results varied in the degree of dehydration induced, as well as in the degree of sterility of the tissue. In each case there was a definite dehydrating action on the gum by the alcohol, an effect that renders the use of alcohol of these strengths unsuitable for all practical purposes of oral disinfection, even though in some tests

sterility was obtained in 100 per cent of the tests. Tincture of iodine, also dilute tincture of iodine (1:10), was used. With the former *sterility was obtained, but only at the expense of blistering the gum surface. With the latter practically no sterility was obtained.*

TABLE 1

Data on the efficiency of alcohol, ether, acetone, and iodine in efforts to obtain sterility in the buccal cavity.

DRUGS TESTED	PERIOD OF APPLICATION	NUMBER OF CASES	BACTERIOLOGICAL RESULT	EFFECTS ON THE GUMS
	minutes			
Alcohol, 95 per cent	2	5	Sterility in but one case	Gums badly dehydrated
Alcohol, 95 per cent	3	5	Sterility in four cases	Gums badly dehydrated
Alcohol, 60 per cent	2	7	No sterility	Gums not dehydrated
Alcohol, 60 per cent	3	5	No sterility	Gums slightly dehydrated
Alcohol (95 per cent), ether, and acetone, in one-two-three-order	1, for each substance	5	No sterility	Gums badly dehydrated
Alcohol (95 per cent), ether, and acetone, in one-two-three order	2, for each substance	5	Sterility in but two cases	Gums badly dehydrated
Alcohol (95 per cent), ether, and acetone, mixed in equal proportions	2	4	Sterility in but two cases	Gums badly dehydrated
Tincture of iodine	1	3	Sterility in three cases	Gums dehydrated and "burned"
Tincture of iodine, diluted with water (1:10)	1	3	No sterility	Gums apparently not "burned"
Tincture of iodine, diluted with water (1:10)	2	3	Sterility in one case	Gums "burned"
Total.....		45	Sterility in thirteen cases	

Seelig and Gould (22) as early as 1911, definitely proved that alcohol is a good antiseptic in direct proportion to its concentration. The results of our experiments show that the utility of alcohol as an antiseptic, in the strengths referred to (60 per cent and 95 per cent),

is impaired, for oral purposes, by its undesirable dehydrating action on the mucous membranes—one of the effects we have endeavored to overcome. Such dehydration of the oral mucous membranes is objectionable because blistering or burning of the gum follows it, and the ensuing lowered local resistance and subsequent superficial necrosis delay the process of healing and favor the further ingress of microörganisms.

2. Second series. Results with dyes

A. Historical

Leitch (14) used brilliant green in dilute aqueous solution. He found it non-toxic to normal tissue, though antiseptic in action. He also observed that this dye inhibited the growth of staphylococci to a greater extent than it did that of streptococci. The same dye was used, as a paste for injection into wounds, by Short (23) who obtained equally good results. Browning (5) found that brilliant green, 1:2000 in water, is five hundred times as toxic for staphylococci as is Dakin's solution. He also found (4) that it stimulates healthy granulation tissue as well as acts as an antiseptic. Webb (24) and Ligot (15) obtained similar results with the dye.

Browning (2, 1, 3) found that a mixture of crystal violet and brilliant green kills gram-positive cocci chiefly, whereas B. coli, resists its action to a greater extent. He used a solution of 1 per cent of crystal violet and 1 per cent of brilliant green, together in 50 per cent alcohol, with excellent results, and suggested the use of the dye as an antiseptic for mucous membranes.

Graham-Smith (8) found that the toxicity or inhibitory power of crystal violet, as well as various flavines [acriflavine and proflavine, which are acridine dyes, derivatives of acridine, a base found in coal tar (9)], depends to a great extent upon the degree of alkalinity of the solution to which the dye is added—that is, the greater the alkalinity, to a certain degree, the greater is the antiseptic power. For example, crystal violet inhibits the growth of Staphylococcus aureus under the conditions indicated on the next page:[2]

[2] The ratio signifies, in each case, that one part of the dye in the indicated number of parts of aqueous solution, with the reaction stated, is the greatest dilution of the dye, in the particular circumstances, that will completely prevent growth of the organism named.

0.15 n/10 hydrochloric acid	*0.08 n/10 sodium hydroxid*	*0.58 n/10 sodium hydroxid*
1:1,500,000	1:3,500,000	1:5,000,000

Dye tested and medium used	*Organisms studied*		
	Staphylococcus	B. coli	B. pyocyaneus
Crystal violet			
Agar	1:3,500,000	1:10,000	1:10,000
Broth	1:10,000,000		
Brilliant red			
Agar	1:3,250,000	1:1,000	1:1,000
Broth	1:500,000	1:10,000	1:10,000
Quinone			
Agar	1:10,000	1:95,000	1:30,000
Broth	1:60,000	1:100,000	1:10,000
Hydroquinone			
Agar	1:60,000	1:40,000	1:10,000
Broth	1:20,000	1:20,000	1:10,000
Homoflavine			
Agar	1:14,000	1:9,000	1:2,000
Broth	1:300,000	1:250,000	1:30,000

Thus we note that in alkaline media, the dye tends to be more efficient as an antiseptic, at least so far as Staphylococcus aureus is concerned.

According to Marshall (18) the hydrogen ion concentration of saliva varies not only in different individuals, but also in the same individual from time to time. This variation, as has been pointed out by other investigators, may be due to nervous impulses or reflexes which appear to be correlated with such factors as diet, and with the pathology of the oral and gastric mucosae and the teeth.

A small series of experiments was undertaken by us to determine the hydrogen ion concentration (P_H) of saliva by the colorimetric method (with phenolsulfonephthalein as the indicator), according to the procedures of Clark and Lubs (6) and of MacLeod (17), with the following results for P_H in six different specimens: 7.3, 7.3, 7.8, 7.6, 7.3, 7.5; average, 7.43.

The average for P_H, 7.43, indicates a fair degree of alkalinity, which appears to be sufficient to enhance the value of the dye (crystal violet) as an antiseptic.

B. Technical

The solutions to be tested were applied to the gum of the upper jaw between the mucosa of the lip and of the gum beside the frenum, because of the ease with which one may eliminate saliva from the field

by packing with sterile cotton. The dye was applied by means of pledgets of cotton saturated with the dye solution of various strengths and for different periods. Bacterial cultures were made in glucose-veal bouillon, and on glucose-blood agar slants or plates, by the use of sterile swabs, kept in the individual test tubes in which they were sterilized.

C. Results with brilliant green (saturated solution in alcohol)

A saturated solution of brilliant green[3] in 95 per cent alcohol or in 60 per cent alcohol, was applied, as indicated above, and the swab cultured after one minute of application. A second test was subse-

TABLE 2

Data on the efficiency of alcoholic solutions of brilliant green in efforts to obtain sterility in the buccal cavity

SOLUTION OF BRILLIANT GREEN	PERIOD OF APPLICATION	NUMBER OF CASES	BACTERIOLOGICAL RESULT	EFFECTS ON THE GUMS
	minute			
Saturated, in 95 per cent alcohol	1	5	Sterility in five cases	Gums badly dehydrated
Saturated, in 60 per cent alcohol	1	5	Sterility in five cases	Gums only slightly dehydrated
Saturated, in 95 per cent alcohol	1	5	Sterility in five cases	Gums very badly dehydrated
Followed by washing with 95 per cent alcohol	0.5			
Saturated, in 60 per cent alcohol	1	5	Sterility in five cases	Gums only slightly dehydrated
Followed by washing with 60 per cent alcohol	0.5			
Total.....		20	Sterility in twenty cases	

quently made in which the excess of the dye remaining on the gum was removed by washing with alcohol of the same strength as that used originally to dissolve the dye. The part so treated was then tested for sterility in the usual manner. Sterility was obtained in all cases,

[3] Thus far only Grübler's dyes have been used in this work.

but the alcohol exerted too great a dehydrating action upon the mucous membrane to permit of its routine application. The results are summarized in *table 2*.

D. Results with brilliant green (1 per cent solution in 50 per cent alcohol)

In this group of tests the technique was similar to that of the tests in section C, except that we used a 1 per cent solution of brilliant green in 50 per cent alcohol. Sterility was obtained in 78.5 per cent of the cases and there was only a slight degree of harmful effect of the alcohol upon the gums. The results are shown in *table 3*.

TABLE 3

Additional data on the efficiency of brilliant green in alcoholic solution in efforts to obtain sterility in the buccal cavity

SOLUTION OF BRILLIANT GREEN	PERIOD OF APPLICATION	NUMBER OF CASES	BACTERIOLOGICAL RESULT	EFFECTS ON THE GUMS
	minute			
1 per cent in 50 per cent alcohol	1	7	Sterility in five cases	Gums very slightly dehydrated
1 per cent in 50 per cent alcohol Followed by washing with 50 per cent alcohol	1 0.5	7	Sterility in six cases	Gums very slightly dehydrated
Total.....		14	Sterility in eleven cases (78.5 per cent)	

E. Results with brilliant green and crystal violet in solution *together* (1 per cent of each in 50 per cent alcohol) applied for 1.5 minute

In this series of cases, the dye employed was a mixture of brilliant green and crystal violet, 1 per cent of each in 50 per cent alcohol, applied for 1.5 minute. The action of the dye upon the organisms normally present was measured, in this instance, by taking cultures (a) from the gum-surface before applying the dye, and (b) from the relative numbers of organisms computed to be present in smears of the broth culture, as well as (c) from the number of colonies on plates of enrichment media.

TABLE 4

Data on the efficiency of crystal violet and brilliant green together (1 per cent of each), in 50 per cent alcohol, in efforts to obtain sterility in the buccal cavity. Period of application to the gum: 1.5 minute. (In this, and succeeding tables, the signs, x, xx, and xxx, indicate the relative numbers of organisms in the cultures. Where no such sign is recorded, a pure culture was involved)

CASE NUMBER	ORGANISMS ON THE GUM-SURFACE BEFORE THE DYE WAS APPLIED	RESULTS AFTER THE DYE SOLUTION HAD BEEN APPLIED	RESULTS AFTER THE EXCESS OF THE DYE HAD BEEN REMOVED BY WASHING WITH ALCOHOL	TYPE OF CASE
17	Streptococci xxx Diplostreptococci x	Sterile in 48 hours	Same	Pyorrhea
18	Diplostreptococci xxx Streptococci, short chain x Staphylococcus albus x	Sterile in 48 hours	Same	Pyorrhea
19	B. acidophilus xxx Diplostreptococci xx Streptococci x	Diplostreptococci present	Same	Pyorrhea
20	Diplostreptococci xxx Streptococci xx Staphylococcus albus x	Sterile in 36 hours	Same	Pyorrhea
21	Diplostreptococci xxx Staphylococcus albus x Streptococci x	Sterile in 36 hours	Same	Pyorrhea
22	Diplostreptococci xxx Streptococci x	Sterile in 36 hours	Same	Pyorrhea
23	Diplostreptococci xxx Staphylococcus albus x	Sterile in 36 hours	Same	Pyorrhea
24	Diplostreptococci xxx Streptococci x	Sterile in 36 hours	Same	Pyorrhea
25	Streptococci, long chain xxx Staphylococcus albus xxx	Streptococci, long chain present	Same	Pyorrhea
26	Streptococci xxx Diplostreptococci x	Sterile	Same	Pyorrhea
27	Staphylococcus albus xxx Streptococci, short chain xxx	Sterile in 48 hours	Same	Pyorrhea

TABLE 4—*Concluded*

CASE NUMBER	ORGANISMS ON THE GUM-SURFACE BEFORE THE DYE WAS APPLIED	RESULTS AFTER THE DYE SOLUTION HAD BEEN APPLIED	RESULTS AFTER THE EXCESS OF THE DYE HAD BEEN REMOVED BY WASHING WITH ALCOHOL	TYPE OF CASE
28	B. acidophilus xx Streptococci, short chain xx Staphylococcus albus x	Gram-rod-like organism present	Same	Pyorrhea
29	Diplostreptococci xxx Streptococci, short chain xx	Sterile in 48 hours	Same	Pyorrhea
30	Streptococci, long chain xx Staphylococcus aureus x	Sterile in 36 hours	Same	Pyorrhea
Total number of cases, 14. Sterility in the number of cases indicated below:				
		11 cases; 78.5 per cent	10 cases; 75 per cent	

By comparing these results with those obtained *after* swabbing the gum-surface with the dye, and after the subsequent removal of the excess of the dye with 50 per cent alcohol, a direct determination of the sterilizing action of the fluids could be made. The cases were all diagnosed as pyorrheal. Sterility was obtained in 75 per cent of them. The results are given in *table 4*.

F. Results of tests similar to those in the last preceding section (E), with additional bacteriological precautions

In addition to the previous precautions and technique, this series of experiments was further controlled by planting the last swab, used in culturing the gum-surface, in glucose-veal broth. In this series of tests we obtained sterility in 80 per cent of the cases. The findings are given in *table 5*.

TABLE 5

Additional data on the efficiency of crystal violet and brilliant green together (1 per cent of each), in 50 per cent alcohol, in efforts to obtain sterility in the buccal cavity. Period of application to the gum: 1.5 minute.

CASE NUMBER	ORGANISMS ON THE GUM-SURFACE BEFORE THE DYE WAS APPLIED	RESULTS AFTER THE DYE SOLUTION HAD BEEN APPLIED	RESULTS AFTER THE EXCESS OF THE DYE HAD BEEN REMOVED BY WASHING WITH ALCOHOL	RESULT IN THE CULTURE OF THE LAST SWAB	TYPE OF CASE
31	Streptococci xxx Diplostreptococci x Staphylococci x	Present: Streptococci xx Diplostreptococci x	Sterile	Sterile	Pyorrhea
32	Streptococci xx Staphylococci x	Sterile in 48 hours	Staphylococcus albus present	Staphylococci present	Pyorrhea
33	Diplostreptococci xxx	Sterile in 48 hours	Same	Same	Pyorrhea
40	Streptococci, long chain xx	Sterile in 36 hours	Same	Same	Pyorrhea
41	Streptococci, long chain xxx Diplostreptococci x	Sterile in 36 hours	Same	Same	Pyorrhea
42	Gram-rod (B. coli) xxx Staphylococci xx	B. coli present	B. coli present	B. coli present	Pyorrhea
43	Streptococci, short chain xxx Staphylococci x Streptococci, long chain x Diplostreptococci x	Sterile in 48 hours	Same	Same	Pyorrhea
46	Staphylococcus albus xx Streptococci x	Sterile in 48 hours	Same	Same	Pyorrhea
47	Diplostreptococci xx Streptococci, short chain x	Sterile in 48 hours	Same	Same	Pyorrhea
49	Diplostreptococci xxx Streptococci x Staphylococcus albus x	Sterile in 48 hours	Streptococci present	Sterile in 48 hours	Pyorrhea
Total number of cases, 10. Sterility in the number of cases indicated below:					
		8 cases; 80 per cent	7 cases; 70 per cent	8 cases; 80 per cent	

TABLE 6

Data on the comparative efficiency of crystal violet and brilliant green together (1 per cent of each) and of hydroquinone (1 per cent) in aqueous solution, in efforts to obtain sterility in the buccal cavity. Periods of application to the gum: (a) crystal violet and brilliant green, 2 minutes, or 2.5 minutes; (b) hydroquinone, 2.25 minutes. Type of cases: all pyorrhea

CASE NUMBER	ORGANISMS ON THE GUM-SURFACE BEFORE THE DYE WAS APPLIED	RESULTS AFTER THE DYE SOLUTION HAD BEEN APPLIED FOR 2 MINUTES	RESULT IN THE LAST CORRESPONDING SWAB CULTURE	RESULTS AFTER THE DYE SOLUTION HAD BEEN APPLIED FOR 2.5 MINUTES	RESULT IN THE LAST CORRESPONDING SWAB CULTURE	RESULTS AFTER THE HYDROQUINONE SOLUTION HAD BEEN APPLIED FOR 2.25 MINUTES
60	Streptococcus xxx Diplostreptococcus x	Same	Same	Same	Same	Same
61	Streptococcus xx Diplostreptococcus x Staphylococcus albus x	Streptococcus present	Present: Streptococcus xx Diplostreptococcus x	Streptococcus present	Streptococcus present	Same as control (first column)
62	Streptococcus x Diplostreptococcus x	Same	Same	Same	Same	Same
63	Staphylococcus xxx Streptococcus xx	Streptococcus present	Present: Streptococcus xx Staphylococcus x	Streptococcus present	Streptococcus present	Same as control (first column)
64	Streptococcus xx B. coli x	Same	Same	Same	Same	Same
65	Streptococcus	Same	Same	Same	Same	Same
66	Streptococcus xx Staphylococcus xx Diplostreptococcus x	Present: Streptococcus x Staphylococcus x	Present: Streptococcus x Staphylococcus x Diplostreptococcus x	Present: Streptococcus x Staphylococcus x	Same	Same as control (first column)
67	Staphylococcus xx Streptococcus x	Same	Same	Same	Same	Same

TABLE 6—*Concluded*

CASE NUMBER	ORGANISMS ON THE GUM-SURFACE BEFORE THE DYE WAS APPLIED	RESULTS AFTER THE DYE SOLUTION HAD BEEN APPLIED FOR 2 MINUTES	RESULT IN THE LAST CORRESPONDING SWAB CULTURE	RESULTS AFTER THE DYE SOLUTION HAD BEEN APPLIED FOR 2.5 MINUTES	RESULT IN THE LAST CORRESPONDING SWAB CULTURE	RESULTS AFTER THE HYDROQUINONE SOLUTION HAD BEEN APPLIED FOR 2.25 MINUTES
68	Diplostreptococcus xx Streptococcus x	Same	Same	Same	Same	Same
69	Streptococcus xx B. coli xx Diplostreptococcus x Staphylococcus x	Same	Same	Present: Streptococcus xx B. coli xx Diplostreptococcus x	Same	Same as control (first column)

G. Results of tests with brilliant green and crystal violet in solution *together* (1 per cent of each in aqueous solution) compared with hydroquinone (1 per cent aqueous solution)

At this stage we considered it advisable to ascertain the relative value of an *aqueous* solution of the dyes compared with an aqueous solution of hydroquinone. Accordingly we made a solution of brilliant green and crystal violet (1 per cent of each, together), and another of hydroquinone (1 per cent), in sterile distilled water. The bacteriological technique was the same as that outlined for the tests in section F.

The results, as shown in *table 6*, were wholly unsatisfactory, from an experimental point of view, for practically no sterility was obtained under the conditions of the tests.

H. Results of a repetition of the tests with brilliant green and crystal violet in solution *together* in alcohol (section E), with an extension of the period of application to the gum (from 1.5 minute) to 2 minutes

We repeated the technique of the tests in section E (with 1 per cent each of brilliant green and crystal violet together in solution in 50 per cent alcohol), but allowed a little more time for the action of the

TABLE 7

Additional data on the efficiency of crystal violet and brilliant green together (1 per cent of each), in 50 per cent alcohol, in efforts to obtain sterility in the buccal cavity. Period of application to the gum: 2 minutes

CASE NUMBER	ORGANISMS ON THE GUM-SURFACE BEFORE THE DYE WAS APPLIED	RESULTS AFTER THE DYE SOLUTION HAD BEEN APPLIED	RESULT IN THE CULTURE OF THE LAST SWAB	TYPES OF CASES
65/2	Streptococcus xx Diplostreptococcus x	Sterile in 48 hours	Sterile in 48 hours	Pyorrhea
66/2	Streptococcus	Sterile in 48 hours	Sterile in 48 hours	Pyorrhea
67/2	Diplostreptococcus xx Streptococcus	Sterile in 48 hours	Sterile in 48 hours	Pyorrhea and caries
68/2	Staphylococcus albus xx Streptococcus x	Sterile in 48 hours	Sterile in 48 hours	Pyorrhea
69/2	Streptococcus	Sterile in 48 hours	Sterile in 48 hours	Edentulous
70	Diplostreptococcus x Staphylococcus x	Sterile in 48 hours	Sterile in 48 hours	Pyorrhea
71	Diplostreptococcus xx Streptococcus x Staphylococcus albus x	Sterile in 48 hours	Sterile in 48 hours	Pyorrhea
72	Streptococcus, long chain xx Streptococcus, short chain xx Staphylococcus x Diplostreptococcus x	Streptococcus, long chain, present	Streptococcus, long chain, present	Pyorrhea
73	Staphylococcus albus	Sterile in 48 hours	Sterile in 48 hours	Pyorrhea
75	Streptococcus x Diplostreptococcus x	Sterile in 48 hours	Sterile in 48 hours	Pyorrhea
76	Diplostreptococcus xx Staphylococcus x	Sterile in 48 hours	Sterile in 48 hours	Pyorrhea
77	Diplostreptococcus xxx Staphylococcus x Streptococcus, long chain x	Sterile in 48 hours	Sterile in 48 hours	Pyorrhea

TABLE 7—*Continued*

CASE NUMBER	ORGANISMS ON THE GUM-SURFACE BEFORE THE DYE WAS APPLIED	RESULTS AFTER THE DYE SOLUTION HAD BEEN APPLIED	RESULT IN THE CULTURE OF THE LAST SWAB	TYPE OF CASES
78	Streptococcus xxxx Diplostreptococcus x	Sterile in 48 hours	Sterile in 48 hours	Pyorrhea and caries
79	Streptococcus xx Staphylecoccus albus x Diplostreptococcus x	Staphylococcus albus present	Staphylococcus albus present	Pyorrhea
80	Streptococcus, long chain	Sterile	Sterile	Edentulous
81	Diplostreptococcus xx Streptococcus x	Sterile	Sterile	Advanced caries
85	Staphylococcus albus x Diplostreptococcus x	Sterile	Sterile	Pyorrhea
86	Streptococcus xxx Diplostreptococcus x	Sterile	Sterile	Pyorrhea
87	Diplostreptococcus xx Streptococcus x Staphylococcus albus x	Sterile	Sterile	Pyorrhea
88	Staphylococcus albus xx Streptococcus x	Sterile	Staphylococcus albus present	Pyorrhea
89	Streptococcus	Sterile	Sterile	Pyorrhea
90	Diplostreptococcus xx Streptococcus x	Sterile	Sterile	Pyorrhea
92	Streptococcus, long chain xx Streptococcus, short chain x Staphylococcus albus x	Sterile	Sterile	Fairly clean mouth
93	Diplostreptococcus xxx Streptococcus x	Sterile in 48 hours	Sterile in 48 hours	Pyorrhea
94	Diplostreptococcus	Sterile in 48 hours	Sterile in 48 hours	Pyorrhea

TABLE 7—*Concluded*

CASE NUMBER	ORGANISMS ON THE GUM-SURFACE BEFORE THE DYE WAS APPLIED	RESULTS AFTER THE DYE SOLUTION HAD BEEN APPLIED	RESULTS IN THE CULTURE OF THE LAST SWAB	TYPES OF CASES
95	Streptococcus xxx Staphylococcus xx Diplostreptococcus x	Sterile in 48 hours	Sterile in 48 hours	Pyorrhea
96	Streptococcus x Diplostreptococcus x	Sterile in 48 hours	Sterile in 48 hours	Pyorrhea
97	Staphylococcus albus xx Streptococcus x	Sterile in 48 hours	Sterile in 48 hours	Pyorrhea
98	Streptococcus xxx Diplostreptococcus xx	Streptococcus present	Streptococcus present	Pyorrhea
99	Diplostreptococcus xx Streptococcus x	Streptococcus present	Streptococcus present	Pyorrhea
101	Streptococcus x Staphylococcus albus x	Streptococcus present	Streptococcus present	Pyorrhea
102	Streptococcus	Streptococcus present	Streptococcus present	Pyorrhea
103	Streptococcus xx Diplostreptococcus x	Streptococcus present	Streptococcus present	Pyorrhea
104	Diplostreptococcus xxx Staphylococcus albus x Streptococcus x B. coli xx	B. coli present	B. coli present	Pyorrhea
105	Streptococcus xx Staphylococcus albus x	Sterile	Sterile	Pyorrhea
106	Streptococcus xxx Staphylococcus albus xx	Sterile	Sterile	Pyorrhea
108	Diplostreptococcus xxx Streptococcus x	Sterile	Sterile	Pyorrhea

dye, namely, 2 minutes instead of 1.5 minute. The results in *table 7* are summarized below:

	Number	*Per cent*
Total number of cases cultured	37	
Sterile after application of the dye for two minutes	33	89.2
Sterile swabs	32	86.9
Staphylococcus persisted after the application of the dye	1	2.8
Streptococcus persisted after the application of the dye	1	2.8

In this series of tests, and in those of the preceding groups, we noted that B. coli was not affected by the dye to any appreciable extent. We endeavored, then, to ascertain the comparative effects of the dye on B. coli and on a streptococcus. See the experiment described in the footnote.[4]

[4] The supernatant fluid from a 100 cc. glucose-blood veal-broth culture of a streptococcus isolated from an apical infection was carefully pipetted off and centrifuged. The organisms thus obtained were suspended in normal salt solution and half their number, 500 billions, injected into the ear veins of a rabbit. The rabbit was sacrificed in ten minutes, immediately placed in 1:1000 lysol solution, and carefully autopsied. Portions of the liver, lungs, heart, and kidneys were obtained aseptically and placed in sterile petri dishes. Several pieces of each of these tissues, 0.5 x 0.5 x 1 cm. in size, were dipped into a suspension of B. coli. One of these pieces was then immersed for five seconds in paraffin oil at 180°C., when it was macerated in a sterile mortar in broth and sand, and plated in glucose-blood agar; also in Endo's medium according to the method of McMaster (16). Others of the pieces treated with B. coli were dipped in a solution of brilliant green and crystal violet together (1 per cent each) in 50 per cent alcohol for 1.5 minute and the excess of the dye washed off with 50 per cent alcohol for 0.5 minute. The tissue was finally macerated as in the case of the pieces immersed in paraffin oil, with the following results:

TISSUE TREATED WITH B. COLI	AFTER IMMERSION IN PARAFFIN OIL AT 180°C. FOR 5 SECONDS		AFTER APPLICATION OF THE DYE SOLUTION — CRYSTAL VIOLET AND BRILLIANT GREEN TOGETHER (1 PER CENT OF EACH) IN 50 PER CENT ALCOHOL — FOR 1.5 MINUTE FOLLOWED BY WASHING WITH 50 PER CENT ALCOHOL FOR 0.5 MINUTE	
	Organisms in Endo's medium	Organisms in the glucose-blood broth	Organisms in Endo's medium	Organisms in the glucose-blood broth
Heart	No growth	Streptococci	B. coli	Streptococci and B. coli
Kidney	No growth	Streptococci	B. coli	Streptococci and B. coli
Lungs	No growth	Streptococci	No growth	Streptococci
Liver	No growth	Streptococci	No growth	Streptococci

These tests show that in the second case, i.e., with the dye, there was no growth of B. coli in the cultures from the lungs and liver, possibly because of the better penetration of the dye into the lungs and liver, as a consequence of the peculiarities of the anatomical structure of these tissues.

I. Results of a repetition of the tests with brilliant green and crystal violet *together* in alcohol, in the last preceding section (H), after previous thorough flushing of the mouth with an alkaline wash and brushing of the teeth

After carefully flushing the mouth with an alkaline wash and brushing the teeth, the technique for the tests in section H was used, with the results shown in *table 8*.

TABLE 8

Additional data on the efficiency of crystal violet and brilliant green together (1 per cent of each), in 50 per cent alcohol, in efforts to obtain sterility in the buccal cavity. Period of application to the gum: 2 minutes (after flushing the mouth with an alkaline wash and brushing the teeth)

CASE NUMBER	ORGANISMS ON THE GUM-SURFACE BEFORE THE DYE WAS APPLIED	RESULTS AFTER THE DYE SOLUTION HAD BEEN APPLIED	RESULT IN THE CULTURE OF THE LAST SWAB	TYPES OF CASES
110	Streptococcus	Sterile	Sterile	Pyorrhea
111	Streptococcus	Sterile	Sterile	Pyorrhea
112	Staphylococcus	Sterile	Sterile	Pyorrhea
113	Streptococcus x Diplostreptococcus	Sterile	Sterile	Pyorrhea
114	Streptococcus	Sterile	Sterile	Pyorrhea
115	Diplostreptococcus	Sterile	Sterile	Pyorrhea
116	Diplostreptococcus xx Streptococcus x	Sterile	Sterile	Extensive caries
117	Diplostreptococcus	Sterile	Sterile	Pyorrhea
118	Streptococcus	Streptococcus present	Sterile	Pyorrhea
119	Diplostreptococcus xx Streptococcus x	Sterile	Sterile	Pyorrhea
120	Staphylococcus	Sterile	Sterile	Pyorrhea
121	Streptococcus xxx Diplostreptococcus x	Sterile	Sterile	Pyorrhea
122	Streptococcus	Sterile	Sterile	Pyorrhea
123	Streptococcus, long chain x Streptococcus, short chain x	Sterile	Sterile	Pyorrhea

Total number of cases: 14; sterility in 13 cases, or 92 per cent; absolute sterility in 14 cases or 100 per cent.

3. General discussion of the results of the first two series of tests

Alcohol and iodine should be rejected as oral antiseptics on account of their harmful effects on the delicate mucous membrane despite their apparently good qualities as antiseptics elsewhere.

Since neither crystal violet nor brilliant green is much affected by the oral secretions, and as the action of each is enhanced by the slight alkalinity of the saliva, we regard these dyes as excellent oral antiseptics, in accord with the findings recorded in sections D, E, F, H, and I above.

The results of the tests described in section I, show that advantage may be derived from a thorough cleansing of the mouth and teeth before applying the antiseptic. The alkaline mouth-wash employed in the tests for this purpose appears to have been responsible for the improvement of the results (I).

4. Third series. Clinical findings

The results of the foregoing experiments show the efficiency of dyes as antiseptics from the laboratory view-point. Consequently, we endeavored to ascertain their value from the clinical and therapeutic aspects.

The following case histories have been selected from a very large number to *illustrate* the effects of practical application, in dental surgery, of crystal violet and brilliant green in solution together (1 per cent of each in 50 per cent alcohol), referred to below as "the dye."

Case 1. Mr. J. A. An extensive bone cyst in the mandible. It was opened, curretted, drained, and treated with the dye. The discharge, which had been profuse and purulent, became scanty and serous after two applications with a one-day interval. Granulations began to grow inward from all sides. The wound gradually closed up in four weeks of this treatment.

Case 2. Mr. M. S. A rather large granuloma, and surrounding infected bone, was incised, curretted, drained, and treated with the dye. Granulations grew rapidly and healing was by first intention.

Case 3. Mr. J. F. An osteomyelitis of the lower third of a fibula. It was opened, drained, and treated with camphor-phenol for one month without improvement and with a continuing profuse, purulent, foul discharge. The dye was applied and the discharge soon became scanty, serous and odorless. Two small sequestra were recently removed. Healing began promptly after the operation and is proceeding rapidly.

Case 4. Mrs. J. A surgical removal of granulomata and the surrounding necrotic bone. The wound was treated with the dye. Healing took place promptly, with no discharge save in one area, which is yielding rapidly to treatment with the dye.

Case 5. Mr. J. H. A severe case of pyorrhea. Teeth were removed. The wounds were treated with the dye three times. There has been no history of pain or soreness. Healing progressed at a rapid rate.

Case 6. Mrs. B. Extensive apical and periapical infections. Teeth were surgically removed. The wounds were treated once weekly, for three weeks, with the dye. Healing was complete with almost no discharge. Dentures were constructed in the third week after the extractions.

Case 7. Mr. R. A superior first molar was removed surgically under local anesthesia. A severe case of eburnated bone. Treated twice with the dye. Healing was complete in five days, with no discharge.

Case 8. Miss C. Granulomata and necrosis about lower first and second molars. These were removed under local anesthesia, with extensive currettage. The wounds were treated daily, for a week, with the dye. There were slight, scanty, serous discharges, but no pain. The wounds were completely healed in three weeks.

Many other cases might be mentioned, in which the results were quite similar. In the research laboratories and clinics of the dental department a large number of patients have been treated with the dye. The histories of these cases appear to confirm the general deduction stated above regarding the antiseptic value of the dye. The improvement in cases of chronic gingivitis has been very marked. Injection of the dye into pyorrheal pockets is of only temporary benefit, however, for the tendency toward tissue degeneration is not noticeably altered.

Discussion of the clinical findings

Solutions of crystal violet and brilliant green may be easily applied to the gums and even deeper structures in the oral cavity. The diffusion and penetration of the dye is considerable. The clinical data reported above are wholly in keeping with the results that various observers have obtained with dyes as antiseptics for other parts of the body. In every instance, in our experience, the case was benefited by treatment with the dye. Extractions, old discharging sinuses and old infections, yield completely to treatment.

Solutions of crystal violet and brilliant green appear to have no lasting beneficial effect upon pyorrhea. The only result we obtained was merely a temporary diminution in the severity of the symptoms.

III. SUMMARY OF GENERAL CONCLUSIONS

Brilliant green and crystal violet, in solution together (1 per cent of each in 50 per cent alcohol), are very efficient, mild antiseptics. This combination has very little, if any, harmful effect on the delicate mucous membrane of the mouth.

Clinical observations indicate that these dyes together in alcohol act not only as an antiseptic, but also as a mild stimulant to newly forming granulations, both by keeping down contamination by oral organisms and by either destroying or inhibiting the growth of organisms initially present.

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ORAL SEPSIS AND INTERNAL MEDICINE[1]

LEWELLYS F. BARKER

Johns Hopkins University Medical School, Baltimore, Maryland

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INTRODUCTION

When the chairman of your executive committee wrote me, inviting me to address you tonight on this subject, I felt that it was not only a privilege to come, but a real duty, for I realize that the members of the medical profession and those of the dental profession must combine in the work of preventing and curing the general diseases that may result from infection in and about the teeth.

The subject is a large one. There are many of us in the medical professsion who are still not fully awake to its importance, and there may be some among you who are not yet sufficiently aware of the relation of dental infections to diseases elsewhere in the body.

Not that I have anything new, perhaps, to say to you; I think I shall rather re-emphasize facts that are well known to most of

[1]Address delivered, by invitation, before the First District Dental Society of the State of New York, at a meeting in New York City, December 1, 1919. See page v, of the section on Proceedings of Dental and Stomatological Societies, for a report of the discussion of this address at that meeting, by Drs. Henry W. Gillett, Byron C. Darling, N. T. Shields, M. L. Rhein, and H. J. Kauffer, of New York City; and Dr. Barker.—(Ed.)

you, and try to give you the impressions of a general diagnostician in regard to those problems with which you deal every day.

The dentist makes a diagnosis and applies treatment in a circumscribed domain. The medical practitioner who makes a general diagnostic survey has to deal with the whole body, the mind and the social situation of the patient; and he often finds relationships between the lesions in circumscribed domains and the situation as a whole that might be overlooked by the worker in a circumscribed domain.

Much that I have learned with regard to oral sepsis and its relation to general and to systemic disease has been the result of a close relation between the Medical Clinic and the Dental Clinic at the Johns Hopkins Hospital. I am ashamed to say that the Dental Clinic was begun there only a few years ago. It should have been begun much earlier; but, since its organization, its work has been increasing rapidly, and we should now consider ourselves culpable, if, when the teeth look suspicious, we did not have a full dental report on patients who present themselves for diagnosis and treatment of any obscure infectious, or other, disease-process.

Much of the advance in knowledge of oral sepsis has been due to work conducted as a result of your dental research endowments. I think it is highly to the credit of the dental profession that it has provided endowments for the study of the etiology of oral sepsis, and of the pathological conditions that result from infections in and about the teeth and gums.

There are many diseases of the teeth other than septic infections that are related to internal medicine, but I shall not attempt to deal with them tonight. I shall confine my remarks to comments upon the general conditions that I have met with, or that others have met with, in association with infectious processes about the teeth and gums. Such infections are divisible into two groups: (1) gingivitis, pyorrhoea alveolaris, and infections about unerupted and impacted teeth; and (2) infections, acute and chronic, at the apices of the teeth, the so-called periodontal infections. These infections can influence the rest of the body in either one of two ways. One way, and a very important way, is by metastatic infection, a few bacteria going through the lymph channels into the blood and setting up a secondary or metastatic infection at some distant point. The other way is

by the absorption, not of the bacteria themselves, but of their toxic products produced *in loco*, those products, after absorption, reaching distant parts of the body and injuring them.

In just how far the diseases secondary to oral sepsis are due to the actual transport of bacteria to distant parts, and in how far they are due to the mere absorption and diffusion of toxic substances produced in the oral infectious foci, it is difficult to say. In certain conditions, I feel very sure, we deal with metastatic infections, that is, with the transport of bacteria, from the oral foci to distant parts. Thus, most of the arthritic infections are real metastatic infections of this sort. On the other hand, in hypertrophic osteo-arthritis, which is in several respects different from ordinary infectious arthritis, I am inclined to think that we may be dealing with the toxic effects of chemical substances absorbed from the primary foci of infection, rather than with the effect of living bacteria transported to the joints. In both instances, however, the joint injury results from the primary sepsis.

I thought it might be interesting to run through the different systems of the body, and to recall to your minds the different kinds of disease that may be associated, and perhaps causally connected, with oral sepsis.

DISEASES OF THE LOCOMOTOR SYSTEM

I shall begin with certain diseases of the locomotor system, especially infectious arthritis, hypertrophic osteo-arthritis, local osteomyelitis, myositis and fibrositis. No one can fail to be impressed by the frequency with which the acute and chronic infectious arthritides are associated with oral sepsis. If there is anything at all that is established regarding focal infections in relation to arthritis, it is that a large proportion of cases of so-called infectious arthritis after adolescence are due to infections about the teeth, the bacteria being transported thence through the blood to the several affected joints, with resulting secondary infection of those joints.

There is this to be said, of course: Infection in the mouth is by no means the only cause of metastatic infectious arthritis. Primary foci of infection anywhere in the body may be the starting point of secondary metastatic arthritis; and general diagnosticians now search,

in cases of infectious arthritis, for such primary foci of infection in various parts of the body. There is a whole series of common sites of primary infections—the tonsils, the antra, the ethmoid cells and the other paranasal sinuses, the mastoid cells, the appendix, the gall bladder, lung cavities, the pleurae, and foci in the urinary and genital systems. If, however, I were asked to give you approximate figures, I should say that at least 80 per cent of the cases of infectious arthritis, including acute articular rheumatism, are secondary to infections in the head (tonsils, adenoids, teeth, paranasal sinuses, mastoids). I think we might even go further in the etiological analysis and say that the primary source within the head in these infections tends to be different in childhood from that in later life. In young children and in adolescents up to the age of twenty, I should say that by far the majority of cases of infectious arthritis are not secondary to diseases of the teeth and gums, but are secondary to infections of the tonsils, or of adenoid tissue, or to infections of the paranasal sinuses. That is not to say that a child may not have arthritis due to a diseased tooth, but certainly the majority of cases in early life are not due to diseased teeth.

In middle life and in later life, on the other hand, only relatively few of the cases of infectious arthritis are due to infected paranasal sinuses and infected tonsils. Though some doubtless are so caused, the majority of those following infections in the head, in my opinion, are due at this time of life to periapical infections of the teeth. I think, therefore, that the age consideration is a help in the search for the primary foci of infection responsible for metastatic arthritis.

Acute rheumatic fever, so-called, is almost always due, we now believe, to metastatic distribution of a virus that attacks primarily the tonsils or adenoids, and not to infections of the teeth; but the severe forms of chronic infectious arthritis, those crippling affections that many doctors call "arthritis deformans," are very often, we think, due to infected teeth. You have doubtless all seen the beneficial effects of getting rid of the primary focus of infection in arresting the progress of some of these cases.

In hypertrophic osteo-arthritis, we deal with a disease of older people. It may be the result of toxic absorption; certainly the occurrence of periapical granulomata and of pyorrhea alveolaris

is very common in patients who suffer from hypertrophic osteo-arthritis.

Physicians, dentists, and patients are disappointed, sometimes, when joint conditions do not clear up quickly after the removal of infected teeth. Diseased joints do, it is true, occasionally clear up like magic, after such removal; but, more often, the recovery is slow. That should not surprise us, for, once metastatic infection of the joints has actually occurred, we have to deal no longer with the primary infection of the teeth alone, but also with multiple secondary infections in the joints. These latter infections often heal only slowly, even after the primary focus has been removed; and each of those secondary foci may, in turn, serve as a primary focus for still other metastatic infections. We must, therefore, not be too much disappointed if an arthritis persists after the surgical removal of an original focus of infection. It is to be borne in mind, too, that several primary foci of infection may exist, in which event the removal of one only would not necessarily prevent the occurrence of further metastatic infections.

Another point I should like to refer to is the "flare-up," or exacerbation, of an arthritis that not infrequently occurs when an infected tooth or other primary focus of infection is treated or removed. Though such "flare-up," when it occurs, is presumptive evidence of a causal relationship between the infective focus and the arthritis, it is not decisive evidence; moreover the failure of such "flare-up" to occur does not exclude, in my opinion, an earlier causal relationship.

In the locomotor system, too, we have to deal with infectious myositis, and with infections of the tendons, fasciae, bursae, and other fibrous tissues—infections that often accompany infectious arthritis. It is reasonable to think that these cases of myositis, teno-synovitis, bursitis, and fibrositis are due to the same primary foci of infection that we believe to be responsible for infectious arthritis. In many instances infected teeth are the primary foci; and these inflammations, as do the arthritides, often clear up after the original infective foci have been removed.

DISEASES OF THE RESPIRATORY APPARATUS

Infections of the respiratory apparatus (which includes the nose, the paranasal sinuses, the larynx, trachea, bronchi, lungs and pleurae) may sometimes be secondary to infections of the teeth and gums. You know, yourselves, how often disease of the antrum, for instance, results from infection propagated from the periapical area of a diseased tooth; and you know, also, how much trouble such an antritis can give to the patient. Sometimes, metastatic (embolic) infection of the lungs appears to be secondary to a primary peridental infection. I have myself seen two such cases, and there are others on record, in which little foci of embolic pneumonia had an oral source. One of the patients had diabetes mellitus; her physician, Dr. W. F. Lockwood, got rid of the infected teeth and the embolic pulmonic process soon cleared up.

DISEASES OF THE CIRCULATORY APPARATUS

One of the commonest diseases of the circulatory apparatus is acute infectious endocarditis, which is always, we believe, a metastatic infection secondary to some primary focus of infection. Here, again, in the majority of cases in young people, the endocarditis is certainly not secondary to peridental sepsis, but, on the contrary, is secondary to primary infection of the tonsils, or of adenoid tissue. Tonsillitis, rheumatic arthritis, endocarditis, and chorea, form a tetrad in the young. The mild vegetative thrombo-endocarditis that occurs in children is a benign form, though it often leaves chronic valvular disease of the heart as a sequel.

In adult life, especially in middle and in later life, it is not at all uncommon to meet with a much more serious form of endocarditis, the so-called subacute infective endocarditis, or endocarditis lenta, which is due to Streptococcus viridans. Streptococcus viridans has to get into the blood before it can cause endocarditis and affect the heart valves. How does it get into the blood? Usually, I believe, from a primary focus in the head, either from infected tonsils or from a periapical granuloma. It is not at all uncommon to have a viridans endocarditis and a viridans septicemia arising from infected teeth. These diseases are most serious infections. I have personally observed

over twenty cases, and every one of the patients is dead. Indeed, I have never seen a patient get well of viridans endocarditis. Dr. Libman, of Mt. Sinai Hospital, has shown us, however, that the disease is not always fatal; for in the bodies of patients, who died later from other causes, he has occasionally observed lesions that must have resulted from a pre-existent viridans endocarditis. But in my own experience (of between twenty and thirty cases) not a single patient suffering from this disease has recovered. It certainly must be a very fatal disease, if our mortality, in a series of cases of the size mentioned, was 100 per cent.

In several of my patients suffering from viridans septicemia and viridans endocarditis, it was possible to demonstrate the presence of Streptococcus viridans in periapical granulomata in the mouth, and I am inclined to believe that these infected granulomata were the source of the vascular infection. The mere presence of Streptococcus viridans in a periapical granuloma does not mean that an endocarditis will follow; for this bacterium is, as you know, obtainable by culture from granulomata in the mouths of large numbers of patients who never develop endocarditis. Further, there is good reason for the belief that in some cases of viridans endocarditis, Streptococcus viridans passes into the blood by way of the tonsils, or through other portals of entry; but I desire at this time to emphasize the fact that the evidence is very strong that Streptococcus viridans not infrequently enters the circulation from granulomatous areas about infected teeth. How very important it is, then, for all of us to keep the fact in mind, to do all in our power to prevent such entrance, and thus to ward off this malignant invader! Other forms of endocarditis, for example, that due to Streptococcus hemolyticus, are also secondary to primary local infective foci.

Like endocarditis, there may also occur a pericarditis, or a myocarditis, secondary to a primary peridental infective focus.

One common form of disturbance of the rhythm of the heart is often met with in association with pyorrhoea alveolaris and with periapical granulomata. I refer to the cardiac irregularity in which premature beats of one ventricle of the heart occur, a condition known as "extrasystolic arrhythmia." The patients, describing their subjective sensations, say that they have a feeling as though the

heart were "turning over." I have known a number of cases, some of them among physicians, where the irregularity disappeared after the teeth and the gums had been put in good condition.

Internists are also coming to the opinion that the presence of infection of any sort in the body predisposes to the development of arterial disease and tends to aggravate arteriosclerosis and increased blood pressure when they exist. We study the mouth, in all cases of arteriosclerosis and of arterial hypertension to see whether or not there is any source of infection there that may be of significance. We do this, not only in cases of arteriosclerosis, but in every patient who comes to us for a general diagnostic study. Every dead tooth is x-rayed, suspicious looking gums are carefully examined; and we have a report from an expert dental diagnostician, which is considered along with the other data accumulated, before we make our final diagnosis. I feel sure that the conditions underlying arterial hypertension may be aggravated by long continued infection, though chronic infection is by no means the only cause; it may, I believe, sometimes be an important contributing factor.

DISEASES OF THE BLOOD AND BLOOD-BUILDING ORGANS

Turning next to the blood, and the blood-building organs, we come to one of the commonest sequels of oral infection, namely, anaemia. Anaemia is, as you know, a broad term, covering a group of conditions in which the blood is impoverished. We have anaemias due to hemorrhage, anaemias due to increased blood-destruction and anaemias due to decreased blood formation. Thus, if a person bleed after an operation, if a woman bleed excessively from the uterus during or between menstrual periods, or if a man bleed even slightly but for a long time from hemorrhoids, we observe, as a sequel, a secondary post-hemorrhagic anaemia. Other secondary anaemias may be due to acute or chronic infection, including oral sepsis.

Whether oral sepsis can be the cause of a primary, or so-called pernicious, anaemia, I do not know; certainly, a majority of patients exhibiting this form of chronic hemolytic anaemia have infected teeth, but this may be merely an accidental association, since it is most often a disease of middle or later life. They exhibit also an

achylia gastrica, that is to say, no free hydrochloric acid is found in the stomach contents of these patients. Some interesting work has recently shown that, in the families of patients who have pernicious anaemia, the children, though not anaemic, exhibit an achylia gastrica. It looks as though the children in these families were born with achylia, and that, in searching for the cause of pernicious anaemia, we may have to look for the primary cause of this achylia. Dead teeth and pyorrhea are very common in pernicious anaemia, and the patients more rapidly secure a remission of symptoms if you clean up the gums and remove any periapical infections. Pernicious anaemia is ultimately fatal, though there may be a number of remissions and exacerbations during its course.

Strikingly beneficial results in secondary anaemia are often obtainable through the thorough treatment of oral sepsis, a fact to which William Hunter, of London, long ago called attention.

May I say a word also about Hodgkin's disease? Many patients suffering from it notice first a swelling in the neck, due to the enlargement of one or more lymph glands there. I saw a patient in Pittsburgh who had had outspoken oral sepsis, and the peculiar diphtheroid bacillus, which is so often present in the glands in Hodgkin's disease, had been found under some bridgework in the man's mouth. It is not at all certain that the diphtheroid bacillus is the cause of Hodgkin's disease, though Bunting and Yates of Wisconsin, as well as others, have brought evidence that is suggestive. In the patient mentioned, the bacteriologist had first reported that a true diphtheria bacillus was present, and the patient was at once treated for diphtheria, but later it was found that he had Hodgkin's disease and that the bacillus found was the diphtheroid bacillus. I think it is quite possible that, in some cases of Hodgkin's disease, the infective agent, whatever it is, gains entrance through an infected mouth; but whether peridental sepsis is ever responsible remains, I think, yet to be found out.

DISEASES OF THE DIGESTIVE SYSTEM

Next, let us consider the relations of oral sepsis to disorders of the digestive system, a topic that I have earlier discussed (at the meeting of the Southern Medical Association in 1916). You are all familiar,

I am sure, with the patients who have pyorrhea alveolaris, or who have multiple periapical granulomata, and who complain also of digestive disturbances, such as gaseous eructations, pain in the epigastrium, lack of appetite, etc. In examinations of the stomach contents of such patients, we may find the signs of sub-acute or chronic gastritis, with either hyperacidity, or, more often, sub-acidity; or there may even be a total absence of hydrochloric acid. The symptoms may clear up quickly after removal of the oral sepsis; although, if hydrochloric acid be absent from the stomach-contents, the patients may have to take acid after meals for the rest of their lives.

Whether a gastric or a duodenal ulcer ever arises as a consequence of oral infection, is a question. It is thought by some that such ulcers are due to local thromboses, and that these in turn are due to metastatic infection from a primary infective focus. Since tooth infection is one of the commonest varieties of primary focal infection, it has been suggested that gastric and duodenal ulcers may, sometimes, be sequelae of periodontitis. The proof would be hard to bring. When there are many possible origins, it would be unwise to lay too much stress upon oral sepsis as a primary cause.

Inflammation of the liver (hepatitis) or of the pancreas (pancreatitis) sometimes follows severe oral sepsis. We once had a man under observation in the Johns Hopkins Hospital who had as extensive a pyorrhoea alveolaris as I have ever seen. His teeth were literally sitting in pus baths. It was in the "emetin days" and an attempt was made to check the pyorrhea with subcutaneous injections of emetin. There was obtained a slight temporary effect, perhaps, but the patient's pyorrhea was beyond the reach, not only of emetin therapy, but also of any kind of therapy that would save the teeth. The only thing to do was to extract, and it was found that not a tooth in either jaw could be saved. He had a liver that was enlarged and tender, the lower margin being at the level of his umbilicus, and his body temperature ranged between 102° and 103°F. Nothing that was done before extraction had any markedly beneficial effect upon the symptoms and physical signs. The hospital dentist extracted all of the teeth, and the mouth soon became free from pus, the temperature quickly fell to normal, and the liver margin soon receded to

the edge of the ribs. The man had been alcoholic, and doubtless had some fatty degeneration and cirrhosis of the liver, but he suffered principally from his oral sepsis and from a toxic hepatopathy secondary to it. He left the hospital very much improved. That was a striking example of a toxic disorder of the liver, due to absorption from a very severe pyorrhea alveolaris.

In diabetes mellitus, due to pancreatic disease, the carbohydrate tolerance seems sometimes to be deleteriously affected by the simultaneous existence of oral sepsis. Cases have been reported in which tolerance for sugar was more easily increased after removal of periapical infection or after treatment of pyorrhea. In diabetes mellitus, as in other chronic diseases, we believe in cleaning up the mouth and getting rid of oral sepsis, if it exist.

DISEASES OF THE UROGENITAL SYSTEM

In the origin of some of the diseases of the urogenital system, oral sepsis may play a rôle. I have seen cases of glomerulo-tubular nephritis—both the acute and the sub-acute forms—which I thought were secondary to oral sepsis, and in which the treatment of the oral sepsis seemed to be of benefit in arresting the process. Tonsillitis is, however, in my experience, a much more common cause of glomerulo-tubular nephritis. It is possible that inflammations of the urinary passages (pyelitis, ureteritis followed by stricture of the ureter, and cystitis) may be due to bacteria entering the blood from foci of infection reaching the kidneys, passing through the renal filter and infecting the urinary tract below.

DISEASES OF THE NERVOUS SYSTEM

There is no doubt, I take it, that oral sepsis can be the primary cause of certain diseases of the nervous system. Thus, multiple neuritis, like arthritis, can, in some instances, be due to toxic absorption from primary foci of infection. Chronic neuralgias, sometimes, can be made to disappear by removal of periapical abscesses. Trigeminal neuralgia (or tic douloureux), as is well known, often owes its origin to infected teeth, and it seems probable that more distant neuralgias (intercostal, brachial, sciatic) may occasionally have a

similar origin. Sciatica is often secondary to inflammation of the sacro-iliac joint, or to arthritis of the lumbar spine; but the inflammations in the spine and the sacro-iliac joint are due, in turn, at least in many instances, to periodontal infections.

Then there is a group of neurasthenic people whose condition is more or less dependent upon the toxic effects of oral sepsis. Of course, neurasthenic conditions may result from any cause that injures the nervous system over a long period. The course of a psychosis may be favorably influenced, it has been asserted, by getting rid of focal infections.

There are, too, certain recurring inflammations in the eye that are undoubtedly secondary to focal infection about the teeth. I would call your attention especially to certain cases of metastatic iritis. A year or more ago I studied a physician from Washington who was having attacks of iritis every few months. Syphilis, one of the common causes of recurring iritis, was ruled out, not only by a negative history, but also by a number of negative Wassermann tests. It was thought that some primary focus of infection must exist, but several attempts to demonstrate such a focus had proven unsuccessful. Roentgenograms of his teeth had been taken before, but the dentists who examined them had said that the teeth were all right. As no other focus could be found, it seemed to me important to have the teeth re-studied. One of our dental consultants examined them, and, about the apex of one of them, found an area that indicated the existence of a granuloma. The tooth was extracted and the socket was curetted. There has been no recurrence of the iritis since.

DISEASES OF THE ENDOCRINIC AND METABOLIC SYSTEMS

Small foci of infection may also, sometimes, influence the ductless glands. Over-activity of the thyroid gland often follows general or local infections. Graves' disease seems always to be due to a production of too much of the secretion of the thyroid gland and is accompanied by hyperplastic changes in the gland. Many different excitants can, probably, stimulate the thyroid gland to produce too much of its secretion. When primary foci of infection exist in the body, the toxins may, sometimes, stimulate the thyroid to over-

activity. We have felt that, by getting rid of focal infection in such cases, we have sometimes been able to exert a favorable influence upon the thyroid disturbance.

Many of the patients who apply to me for a general diagnostic survey exhibit general under-nutrition, being frequently from thirty to fifty pounds under calculated ideal weight. These patients often feel "below par" and complain of weakness, nervousness, and incapacity for work. In treating them, we always try to get rid of any primary foci of infection that exist and then make the patients eat enough and rest enough to gain weight. To restore such patients to health, it is often helpful to put them to bed for a few weeks. Most of them are convinced that they must exercise to have an appetite and to gain weight. They have, however, become so emaciated, and have exhausted their nervous systems so much, that they cannot digest their food when exercising. If they will consent to a complete rest in bed for a time, they can often be made to eat like farmhands; and in the course of six or eight weeks they may gain twenty pounds in weight and be soon on the way back to health and strength.

NECESSITY FOR, AND DIFFICULTIES IN THE WAY OF, CLOSE COÖPERATION BETWEEN PHYSICIANS AND DENTISTS

You have patiently listened to my description of a whole series of conditions in which I believe oral sepsis may be of importance as an etiological factor. I have referred to certain disorders of the locomotor system, the respiratory system, the circulatory system, the blood and haematopoietic system, the digestive system, the genito-urinary system, the nervous system, and the endocrinic and metabolic systems, in each of which there is reason to believe that infective conditions about the teeth may play a part. Surely it is an account large enough to emphasize the importance of the relationship of dentistry to internal medicine. Obviously without the closest association of members of the dental and medical professions many patients will unnecessarily suffer. In making general diagnostic surveys of patients the importance of expert dental examinations dare not be underestimated. Physicians and dentists must learn how best to work together, if they would be successful in untangling the disease-skein in more obscure cases.

There are many difficulties. First, we who are medical men have found out that there are still some dentists who are unaware of the importance of these relationships of oral infections to other diseases, and who permit their patients to keep teeth that they should not keep. It may not be the case in New York, but it is in Baltimore, that some dentists still allow patients to retain teeth that should be extracted. There are, too, some dentists, who, though aware of the importance of peridental infection, do not make use of a therapy that is adequate; they adopt means of treating these cases that are insufficient, and so do not obtain the results they desire.

On the other hand, we have found that there are some dentists who are too radical, who, sometimes, take out teeth that could safely be retained by the patient without injury to his body as a whole.

You who are dentists have found—and I know that I have found—that there are still some physicians who seem to be unaware of the significance of oral sepsis. Many of the arthritic and anaemic patients I have seen have been under the care of one or of several physicians earlier, and despite this, they have sometimes still harbored periapical infections. I am sorry to have to confess it, but it is still necessary to admit that the medical profession has a long way to go in the direction of becoming familiar with the frequency and the dangers of oral sepsis and of taking action that is in accord with present knowledge.

Another difficulty lies in the fact that physicians have been unable to discriminate between the many dentists who are competent to deal with the conditions and the few who are incompetent. Physicians should be, and are, careful to increase the confidence of a patient in his own dentist; but what is a physician to do when he has evidence that a particular dentist is, in respect to oral sepsis, incompetent? A general diagnostic study in a given case of arthritis, may, for example, make a physician feel sure that an arthritis is related to two periapical granulomata, clearly visible in dental films; he sends the patient to see his dentist, who says that he "takes no stock in extracting teeth that show periapical areas!" What shall the physician do? Our feeling is that our first duty in such a case is to the patient. We try to work harmoniously with the patient's dentist, but if this dentist declines to do what is, in our opinion, right and necessary

for the patient's welfare, it then may become our duty to refer the patient to another dentist who will.

Let me refer to another difficulty, namely, that experienced by the physician of inducing a patient to have the necessary dental treatment carried out after a report from an expert dentist, telling of abnormal conditions in the mouth, has been received. It is the duty of the physician who, with the aid of an expert dentist, has found that a patient has oral sepsis, to do everything in his power to make the patient do what he ought to do to get rid of it. Some physicians hesitate to urge people to do what they very much dislike to do; and, as you know, most people do not like to give up a tooth that does not feel tender, even though dental and x-ray examinations reveal a large granuloma at its apex. A physician should try very hard in such a case to get the patient to consent to go to his dentist for extraction. Persuasion of this kind has, during the last five years, been frequently resorted to in my own work. In several cases of arthritis I have almost had to compel some of the patients to have infected teeth removed. Fortunately, many of them have subsequently been very grateful for this persuasion that approached compulsion!

Still another difficulty that I would mention is the abuse of tooth extraction by physicians who work independently of expert dentists, and who order wholesale extractions that are not indicated. A patient has chronic rheumatism and the doctor orders all the teeth out without first having a thorough examination made to see how many, if any, teeth are really infected! I have seen some melancholy examples of this; the whole mouth had been cleared of teeth, though the patient asserted that only two or three of the teeth were non-vital and even these had not been examined roentgenologically. Such practice would seem to me very wrong on the part both of the physician in attendance and of the dentist who extracted. The time has come for plain speaking on this point. The "Literary Digest" recently made a long citation from an article on the unnecessary extraction of teeth. We must see to it that this abuse, as far as it exists, is properly censured, for otherwise justifiable extractions will become difficult.

It seems to me that the only sensible thing to do is to take the middle path between ultraradicalism and ultraconservatism. We should never sacrifice a tooth unless we feel that it is an actual menace to the patient who carries it; at the same time, we should try not to allow a patient to retain a tooth when we believe that it is dangerous for him to do so. I would emphasize that it has not seemed to me necessary, or right, to remove a tooth, unless one could demonstrate the existence of some definite pathological change about it, either by palpation or, particularly, by roentgenographic examination. There may be exceptions to this rule, but they are rare.

Much more might be said upon this important subject, but I have already occupied more time than I had intended. In closing, let me again make a plea that dentists and physicians continue to work harmoniously together in trying to arrive at standards of judgment that will insure just diagnostic conclusions. They will thus do much to prevent serious disease; and they will also enlarge their success in curing the diseases that are due to continuing oral infection.

CONCERNING HUMAN CEMENTUM[1]

A. HOPEWELL-SMITH

Evans Dental Institute, University of Pennsylvania, Philadelphia, Pa.

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INTRODUCTION

In complying with the very cordial request of Dr. M. L. Rhein and Dr. F. S. McKay, Chairmen of the Sections on Pathodontia and Periodontia of the First District Dental Society of the State of New York, to make an address this evening, the writer desires to express his lively appreciation of the kind invitation extended to him, and to say that it affords him much pleasure to have an opportunity of re-stating his observations and matured opinions on the subject which has been announced.

While cementum, from a purely histological point of view, is the least interesting of the three calcified dental tissues, chiefly on account

[1] Read at a joint meeting of the Sections on Pathodontia and Periodontia, of the First District Dental Society of the State of New York, held in New York City December 29, 1919. See page xiii of the section of this volume on Proceedings of Dental and Stomatological Societies, for a report of the discussion of this paper at that meeting by Drs. H. J. Kauffer, George Evans, Sr., W. D. Tracy, L. M. Waugh, Theodor Blum, M. L. Rhein, F. S. McKay, Louise C. Ball, N. T. Shields, and I. Hirschfeld, of New York City; and Dr. Hopewell-Smith.—(Ed.)

of the fact that its structure and functions are of a simpler character than those of enamel and dentine, and therefore do not admit of the possibility of so many unsolved problems and so much controversy, its importance as a mechanical and anatomical agent in maintaining the normal articulation of teeth to their attachment to the jaws, cannot be overestimated. Hence it is to be hoped that a brief consideration of this tissue will on this occasion be of interest and profit.

In order to limit the discussion of the subject somewhat, a description of the minute anatomy and physiological properties of this tissue, as found in the teeth of man only, will engage our attention, with only passing references to that of the lower animals.

HUMAN CEMENTUM

When a normal tooth, recently removed from its articulation with the alveolar processes of the maxilla or mandible, is examined macroscopically, it is noticed that, covering the surface of the root, is a white, dense membrane of connective tissue, which presents a remarkable contrast to the smooth, shiny, white, non-lustrous enamel of the crown. This soft tissue is the alveolo-dental periosteum, synonymously termed "pericementum," "peridental," or "periodontal" membrane, or "dental ligament." Of these, the first-named is the most correct and the last the most incorrect, for the tissue intervenes, when *in situ*, between the *lamina dura* of the alveolar process of the bone of the jaw and the cementum, and corresponds with, or is the homologue or analogue, in a modified degree, of the periosteum of bone generally. This modification consists in the fact that, here, this layer of soft connective tissue is placed between two hard substances, whereas the osseous periosteum extends over the free surface of one hard substance only.

On the removal of the alveolo-dental periosteum, the free external surface of cementum is revealed and presents a dull smooth appearance of a whitish-yellow color.

These notes will deal with the following points in connection with a study of cementum: origin, distribution, dimensions, relationships to enamel, chemical composition, histology, histo-pathology, functions, and clinical significance.

Origin (formation and development)

During the development of a tooth from the mesodermic tissue surrounding the dentine papilla, there arises a different arrangement of cells which rapidly and ultimately become changed in shape from round to long fusiform bodies. To this the name of "dental sac," or "dental follicle," or preferably "dental capsule," has been given. It protects the tooth germ from injury during the period of its growth,

FIG. 1. HUMAN (NORMAL) CEMENTUM; PREPARED BY GRINDING, AND STAINED WITH CHLORIDE OF GOLD[2]

Magnified 40 diameters. *C.*—Cementum not yet completely calcified, showing perforating canals and connective-tissue fibres. *H. L.*—Homogeneous layer of dentine, structureless and continuous around the periphery of the dentine of the root. *D.*—Dentine. *P.M.*—Alveolo-dental periosteum.

and is surrounded by the bony crypt of the tooth in its alveolar socket. The dental capsule, having performed this important function during its short existence, is called upon to provide the two dental tissues which are termed cementum and the alveolo-dental periosteum. Of these, the former is derived from its inner, and the latter from its outer, layer.

[2] The original photomicrographs for these illustrations were prepared by the author.

Restricting these remarks to the cementum only, it may be stated that this tissue is deposited on that layer of dentine which is the first formed, and is going to constitute the greater mass of the root of the tooth. Thus, it is apparent that, similar to the crown and cervical portions of the tooth, dentine is developed from without inwards, and cementum, like enamel, from within outwards. In other words, the first-formed dentine and cementum are in close juxtaposition. Whereas the line of demarcation between enamel and dentine is well defined—the amelo-dentinal junction—that between the dentine of the root and the cementum is exceedingly ill defined; so much so that, in sections, it is almost always impossible to determine where one tissue ends and the other begins. In a word, both dentine and cementum are mesodermic in origin, and are derived from cells of a similar histological character and physiological function.

The method of formation of cementum closely resembles that of intra-membranous ossification of bone, namely, the deposit on fibres of connective tissue, called, in the case of bone, osteogenetic fibres, of masses of small globules which are the product of numerous small round cells, functioning as osteoblasts. These are termed by some authors "cementoblasts" on account of their special work—an unnecessary word in the opinion of the writer. These osteoblastic cells build up a solid wall of dense, hard tissue which surrounds the dentine of the roots of teeth, in probably exactly the same manner as the peripheric lamellae (i.e., the sub-periosteal parts) of bone are formed. It therefore follows that the cementum of teeth is the homologue and the analogue of the peripheric lamellae of compact bone.

Distribution

In man and mammals generally, cementum forms the cortex of the radicular dentine of teeth, passing over the whole of the root, with the exception of the apical foramen in a single rooted tooth or the apical foramina in a multi-rooted tooth. In some of the herbivora, in fact in most species of this class of animal, the cementum exists as a coronal covering in addition to uniting groups and denticles of the teeth.

Dimensions

Measurements which the writer has repeatedly made indicate that the tissue is exceedingly thin. Normally it varies in width from 1 μ to 175 or 250 μ, that is, approximately 1/100th of an inch. Compared with this the cutting edge of a knife blade is very broad! The edge of a safety-razor blade is merely a trifle thinner! So fine is this tissue that its surface alone is visible to the naked eye. If a

FIG. 2. HUMAN (NORMAL) CEMENTUM; PREPARED BY GRINDING, UNSTAINED

Magnified 400 diameters. *C.*—Cementum completely calcified. *I. L.*—Incremental lines. *G.*—Granular layer of Tomes. *D.*—Dentine. *P. M.*—Alveolo-dental periosteum.

vertical or horizontal section be made and examined macroscopically, it is impossible to define its narrow limits. Even under the microscope usually it is difficult, as has already been admitted, to ascertain its amount and the exact position of the dentino-cemental junction. This point of the narrowness of the sheet of cementum spread over the roots of teeth is of great importance when considering the questions of its physiological attributes; for it is obvious, from the very

first, that the cementum is too thin to admit of any appreciable amount of the nutrition, vascularization, or innervation, which has been so often claimed for it.

Relationships to enamel

The relationships of cementum to enamel have been examined specially by Choquet (5) and Thorsen (9), the latter of whom studied the matter recently. He found, in sections of the cervical regions of the teeth, that enamel meets cementum, edge to edge, in 30 per cent of cases; is covered by cementum in 60 to 65 per cent; and covers cementum in 0.5 per cent. In 5 to 10 per cent the two tissues do not come in contact at all, a minute portion of the underlying dentine being thus exposed. This area of dentine is sensitive to tactile impressions and becomes frequently the site of erosion.

Chemical composition

The technique of making an accurate analysis of human cementum is so difficult, on account of scarcity of material, and on account of the impossibility (in attempting research) of excluding portions of subjacent dentine from the substance to be examined, that it may at once be stated its chemical composition is unknown. While enamel and dentine have engaged the experiments of Berzelius (1), Galippe (7), Hoppe-Seyler (8), Tomes (10), Evans (6), and others, it has been taken for granted that cementum has the same chemical contents as bone. But this tissue is not bone, not even modified bone. It is a unique substance, even as enamel and dentine are unique anatomical structures. The formula of the chemical make-up of cementum, as given in some text-books, is erroneous and, therefore, entirely untrustworthy.

Histology

Fully formed and perfectly calcified cementum in man is practically without any histological pattern or design. It is devoid of cells, blood vessels, nervous system, lacunae, or connective tissue, for the connective-tissue fibres in which it is developed have lost, in perfect cementum, their outlines and forms, having been completely calcified

and thus blended thoroughly with the matrix of the tissue generally. This matrix is arranged in layers or lamellae which usually run in the same direction as the long axis of the tooth, namely, vertically. Their number is by no means constant. Thus, there may be any number from five or six to twenty or thirty, or more. The lamellae, as shown by Broomell (4), may be wavy in outline and exhibit "varicosities," or transverse bands on examination by transmitted light. By their uniformity it is probable that they are the calcified remains of the original connective tissue fibres, which thus possess a different

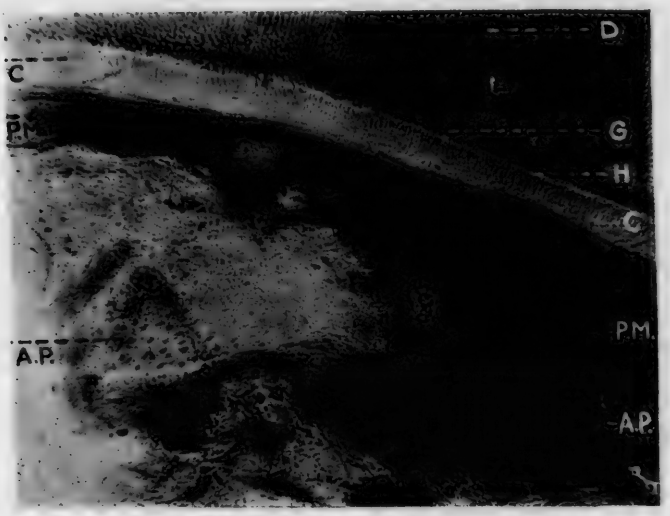

FIG. 3. HUMAN (NORMAL) CEMENTUM (OF MAN AGED SEVENTY-ONE YEARS); PREPARED BY BALSAM IMPREGNATION, AND STAINED WITH ALCOHOLIC BORAX-CARMINE

Magnified 40 times. *C.*—Structureless cementum. *H.*—Homogeneous layer of dentine. *G.*—Granular layer of Tomes. *D.*—Dentine. *P. M.*—Alveolo-dental periosteum. *A. P.*—Bone of the alveolar process of the maxilla.

refractive index from the rest of the matrix. The lamellae appear as unbroken wavy lines. In young, newly-formed tissue they are much thinner, as Broomell has demonstrated, at the cervical margins of the teeth than at their apical regions; and in adult cementum their width is greater, and they are more numerous in the latter than in the former situation. The general appearance of the matrix is either

granular or hyaline, like ground-glass, or composed of many multitudes of amorphous bodies, which undoubtedly are the original calcospherites deposited by the round osteoblastic cells during development.

Bounding and separating the lamellae are several markings called "incremental lines." In some instances these are very pronounced. In perfectly formed tissue, however, they are absent and the whole structure presents a homogeneous ground-glass-like appearance. It may be surmised, therefore, that normal cementum is

FIG. 4. HYPERPLASIC (ABNORMAL) CEMENTUM; PREPARED BY GRINDING, IMPREGNATED WITH COLORED CELLOIDIN

Magnified 250 diameters. *L.*—Large irregular lacunae of the rimous and arborescent types.

nothing more nor less than an extremely thin sheet of glass-like material, which bears a direct histological resemblance to the homogeneous layer of dentine to be presently described. (*Fig. 2.*)

In addition to the lamellae and incremental lines, sections frequently show the presence of thick bundles of white connective tissue fibres, traversing the thickness of the tissue at right or acute angles with the dentine. These are the so-called "perforating fibres,"

which are disposed in broad somewhat irregular canals. They may extend half-way through the tissue. Black (2) considered them, and most probably correctly believed them, to be the semi-calcified remains of the "principal fibres of the periodontal membrane." These fibres can at times be stained with gold chloride; and it is undoubtedly this fact that has given rise to the erroneous assumption that cementum contains protoplasmic filaments. In the earlier editions of his "Dental Anatomy," Sir Charles Tomes described a

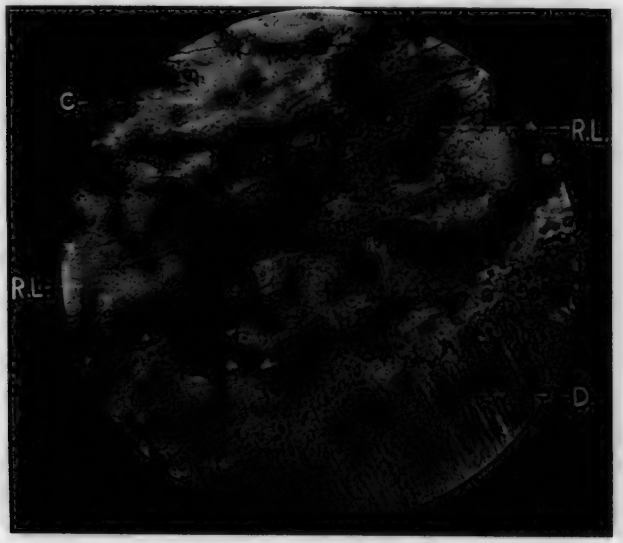

FIG. 5. HYPERPLASIC (ABNORMAL) CEMENTUM; PREPARED BY GRINDING, UNSTAINED

Magnified 45 times. *C.*—Matrix of cementum. *R. L.*—Rimous lacunae, that on the left measuring about 50μ. *D.*—Dentine.

chain of living protoplasm as passing through the cementum from the periodontal membrane on the outside to the dentine on the inner side. Bödecker (3) elaborated that point years ago. The mistake undoubtedly arose from the misconception of the actual events which occur in the calcification and development of the tissue, and the failure to recognize the now undisputed realization of the truth that cementum is formed and calcified like bone in membrane.

There is another class of fibre frequently to be seen in cementum. If sections are decalcified and stained by Bielschowsky's method, Sharpey's fibres are clearly revealed. These can be identified as the perforating fibres in the lamellae of compact bone. They are short, straight or slightly curved bundles of connective-tissue fibres, which penetrate the tissue from without and are totally distinct from the "perforating fibres" already noted. They are truly "penetrating fibres."

FIG. 6. HYPERPLASIC (ABNORMAL) CEMENTUM; PREPARED BY GRINDING, UNSTAINED

Magnified 40 diameters. *D.*—Dentine of root near apical region. *R. C.*—Root canal containing calcified material. *G.*—Granular layer of Tomes. *H. C.*—Cementum containing numerous irregular lacunae of different sizes.

Broomell would recognize three zones or layers in cementum: an inner, granular zone, unbroken and continuous with the homogeneous layer of dentine; an intermediate zone, containing many lacunae, which disappear as complete calcification proceeds; and an outer zone, exhibiting many incremental lines.

As has been already remarked it is obvious that cementum is entirely non-vascular and, therefore, incapable of nourishment or vitality in any degree.

Attention must be directed for a moment to the homogeneous layer of dentine. Immediately external to the granular layer of Tomes, found in the dentine of the roots of human teeth, comes this important layer. It is an exceedingly narrow strip of homogeneous tissue, which is entirely devoid of any histological elements whatsoever. It is bounded externally by the first formed cementum, internally by the granular layer of Tomes. Its importance will be readily conceded when it is pointed out that this homogeneous layer acts, by

FIG. 7. EXTERNAL ABSORPTION OF DENTINE, THE RESULT OF ONE FORM OF LOCAL PERIODONTITIS, WITH HYPERPLASIC CEMENTUM DEPOSITED IN THE ABSORBED AREAS; PREPARED BY GRINDING, UNSTAINED

N. C.—Normal structureless cementum. *H. L.*—Homogeneous layer of dentine. *G.*—Granular layer of Tomes. *D.*—Normal dentine. *A. D.*—Absorption area of dentine. *H. C.*—Hyperplasic cementum with lacunae.

virtue of its position and its structureless character, as an efficient barrier to the outward passage of drugs or medicaments placed in the root canal in the treatment of pulpless teeth. (*Figs. 1, 3 and 7.*)

Assuming that drugs can travel to the utmost extent of the dentinal tubes—and it is to be doubted—it is impossible in normal con-

ditions for them to pass into the cementum and so to the periodontal membrane. Thus, fortunately for mankind, one may use indiscriminately, and without fear of injuring the cementum or periodontal membrane, any or every drug of an escharotic or other nature. Otherwise, there would always be the possibility of the production of inflammation of the periodontal membrane, with subsequent loosening and loss of the teeth.

The foregoing remarks may be applied, without qualification, to the cementum of the deciduous teeth and also to the supernumerary teeth, with the exception that in these instances the cementum is relatively thinner than obtains in the permanent series.

Histo-pathology

Every section of cementum which has become histologically altered through the influence of disturbing factors on its free surface, may exhibit the well-known appearances of hyperplasia, familiar under the name of "exostosis." Again, we have discarded the old and incorrect appellation "exostosis," which is really solely applicable to bone. Every inflammatory condition of the alveolo-dental periosteum, whether acute, sub-acute or chronic, indeed every slight irritation of this membrane, is attended by activity on the part of the osteoblasts covering the surface of the cementum, and results in the formation of new material and the presence of lacunae. When an area has been absorbed and new cementum deposited, lacunae are invariably found in the new material. Now, if hyperplasic cementum be examined with the naked eye or a hand-lens, it may be impossible to see signs of any abnormal change. If it is slight, there may be no appreciable amount of growth or enlargement. There may be, in severer forms, rough cancellous deposits or merely smooth rounded nodules, somewhat like enamel nodules or "pearls." The roots may appear to be elongated and thickened, and are often joined together by the new growth, a condition which gives rise to the term "false gemination," when this is so extensive as to produce a union of one or more teeth. Hyperplasia is not hypertrophy, for the latter implies simple increase in size of the elementary structures of a part, leading to structural changes as a result of increased nutrition. Hypertrophy of the cementum, strictly speaking, cannot therefore exist.

Conspicuously displayed in the hyperplasic cementum are numerous lacunae, spaces or holes, or clefts, in the tissue, totally unlike anything seen elsewhere in the body. If these lacunae are compared with those of normal bone, many points of difference can be readily detected. They are larger, more irregular in outline, possess a greater number of off-shoots or canaliculi than those of bone lacunae. Thus, in size, they may measure, as Kölliker has computed, from 10 μ to 60 μ or more. They are distributed unevenly and unequally

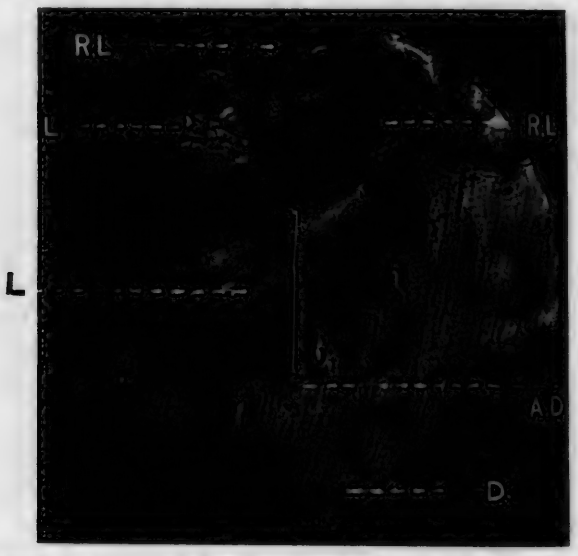

FIG. 8. EXTERNAL ABSORPTION OF DENTINE, THE RESULT OF CHRONIC PERIODONTITIS, WITH HYPERPLASIC CEMENTUM DEPOSITED IN ABSORBED AREAS; PREPARED BY GRINDING, UNSTAINED

D.—Normal dentine. *A. D.*—Absorbed area of dentine. *L.*—Small abrachiate lacunae in hyperplasic cementum. *R. L.*—Rimous lacunae in hyperplasic cementum.

throughout such cementum. Their processes or canaliculi are numerous branched channels, which may extend to from 6 to 8 μ in length. According to their appearance, the lacunae may be variously described as (1) rounded or oval, (2) rimous, like a chink or cleft, (3) arborescent, like a branch of a tree, (4) plumiliform, like a small feather. They may communicate through their off-shoots with one

another by a kind of anastomosis. They may end in free extremities. They may even pass (when the hyperplasic cementum has been absorbed) into the homogeneous layer of dentine and the granular layer of Tomes. (*Fig.* 7.)

What constitutes the contents of these lacunae is known very imperfectly. It may be suggested that they contain air, or are empty; or an atrophied osteoblast may still remain imprisoned *in situ*. It has been argued by Heitzmann and Bödecker that, in the fresh state, they contain protoplasm. This is probably incorrect; and, if it were an established fact, it is difficult to determine the precise rôle of the protoplasm which they are said to contain. The so-called sensitiveness of cementum has been ascribed to the presence of protoplasm in these spaces, but the phenomenon admits of a different and more plausible interpretation. In fact, it is certain that cementum is not sensitive—there are no nerves present in its substance—but that it is capable of transmitting sensations to the underlying dentine.

If the cementum were modified bone, as is so frequently asserted, it is reasonable to expect that osseous ankylosis of the teeth to their sockets would be comparatively frequent, which is not the case. Only ten or a dozen cases in man have been recorded, and it is the rule that, in the lower animals, such ankylosis seldom, if ever, occurs. The reason why osseous ankylosis does not commonly take place is the fact that, while cementum is receiving huge depositions on its surface of added material of a hyperplasic nature, the alveolar socket is undergoing equally extensive changes, in which the bone may either become harder, denser and thicker, i.e., sclerosed, or the opposite, namely, atrophied, shrunken and softened. The former occurs in healthy individuals; the latter, in weak, debilitated subjects whose physiological resistance is low.

Functions

Looking with a broad vision at the question of the functions and uses of cementum, one may say, with little fear of contradiction or refutation, that human cementum exists merely for mechanical purposes. To provide a solid protection for the roots of the teeth,

and to afford attachment for the principal fibres of the periodontal membrane and for the insertion of Sharpey's fibres, would seem to be the only parts it is called upon to play—very important functions too, although essentially automatic ones, affording a strong attachment to the periodontal membrane and, therefore, for the tooth to its containing alveolar socket.

Frequently the palatal roots of maxillary molars become exposed through absorption and disappearance of the internal alveolar plate which normally covers them. Clinically, these roots may be sensitive to thermal and tactile impressions. This is due to the fact that, on account of the extreme tenuity of the layer of cementum over the dentine, stimulations are readily carried through it to the dentine beneath. Cementum cannot generate, but it can and does transmit, impulses made on its free exposed surface to the pulp via the dentinal tubes of the contiguous dentine.

Clinical significance

In conclusion, the clinical significance of the cementum lies in its unique characteristics. It may be stated, as representing the truth of the whole matter, that, like enamel, it is a dense, inert, insensitive, inorganic, non-vascular, extremely narrow layer of tissue, whose sole office is that of affording attachment for a tooth to its articulation. When the pulp has been destroyed and removed from the pulp cavity and root canal, the cementum is unaffected in this respect, possibly also morphologically. It is primarily and essentially affected only by external diseases.

On the assumption that a tooth which fails to respond to properly applied tests for vitality is not alive, it is safe to assert that every pulpless tooth is necessarily a so-called "dead" tooth, but every "dead" tooth is not necessarily a pulpless tooth, for the pulp may exist in the pulp cavity in a condition of fibroid, atrophic, fatty, or calcareous, degeneration. None of these pathological states provokes sensation, or subjective symptoms of pain, or signs of discomfort.

Complete occlusion of the apical foramen is the usual accompaniment of an undue deposition of hyperplasic cementum. In these cases the blood vessels entering and leaving the pulp cavity are no

longer able to carry nutrition to the pulp. The pulp then loses its sensitivity, ceases its functions, and practically remains as dead tissue.

Regarding the nutrition of the dental tissues, it may be positively declared that enamel and cementum are absolutely outside its pale. Nutrition depends upon the presence of an adequate blood supply. There are no blood vessels in either of these tissues, neither are there in human dentine. The latter is, however, partially nourished by an exudation of lymph, from the capillaries and arteries of the pulp, which passes into each dentinal tube. If a fresh sound tooth be cracked open, as in the jaws of a vise, the pulp and the surface of the dentinal walls can be observed to be bathed in a fluid, namely, lymph or serum from the *liquor sanguinis*, circulating in the blood vessels of the pulp.

A "dead" tooth, therefore, incapable of nutrition through removal of the pulp, becomes a foreign body in the mouth.

Living tissue is intolerant of foreign bodies. Dead bone is removed by ulceration in the form of a sequestrum. Dead foetuses are cast off in the course of a precocious parturition. Artificial substances, such as catgut or silkworm ligatures used in operations, become absorbed. Bullets may become absorbed, or remain as innocuous encapsulated masses in muscle or in bone. But in the case of so-called "dead" teeth, as a consequence of the unique nature of cementum and periodontal membrane, the body is tolerant. "Dead" teeth may remain as useful masticatory organs for twenty or more years, though in the long run they become loose by absorption, and by injury done to the alveolo-dental periosteum.

It is universally recognized that a tooth that has been removed from its socket, either by extraction or by dislocation, may regain its former immobility in its articulation with the jaw. This is due, not to repair or regeneration of the periodontal membrane, which is an impossible thing, but to the tooth being held in place by cicatricial tissue which is developed as the result of a traumatic inflammation following as a natural sequence on the injury it has sustained.

The pathological conditions which cementum may undergo are (1) caries, through a bacterial infection of the canals in which Sharpey's fibres run; (2) increase in volume, through the operation of

osteoblasts giving rise to hyperplasia; (3) absorption or decrease in volume, through the activities of phagocytes which digest the hard matrix and excavate its surface, leaving scalloped markings called Howship's foveolae, in which the cells remain; and (4) old-age changes, in which the tissue becomes yellower and more transparent. These pathological phenomena are entirely of a mechanical kind.

Some books refer to necrosis of cementum. This is an impossible condition. Necrosis is a termination of inflammation analogous to gangrene of the soft tissues. It depends essentially on the presence of blood vessels, which, as already noted, do not exist in cementum. When a tooth is spoken of as necrotic, the modern conception of inflammation has been overlooked and a false idea substituted. A tooth may be pulpless or "dead," but never necrotic. The pulp and periodontal membrane are its only constituents which are freely vascularized.

GENERAL REMARKS

On an intimate acquaintance with the minute anatomy of the dental tissues can be built a substantial foundation for certain physiological beliefs, just as in a larger sense theories of metabolism, reflex action, respiration, assimilation, etc., are based on well proven anatomical facts. One cannot but admire the inimitable arrangement of the parts which Nature has given to a perfect tooth (apart from the fact that such a tooth seldom exists in modern man) to make it an efficient instrument primarily for the comminution of food—not only in regard to the anatomy and functions of its enamel, dentine, pulp and cementum, but also to the methods of its attachment to the osseous framework of the jaws. And it is only when interference with Nature and her immutable laws upsets the balance of this arrangement, that one has to cast about for explanations for physiological and pathological phenomena which are directly antagonistic and hurtful to the well-being of the teeth, and to the individual to whom they belong.

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PROGRESSIVE DENTISTRY AND STOMATOLOGY

2. Periodontology, with Special Reference to Periodontoclasia[1]

ARTHUR H. MERRITT

New York City

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INTRODUCTION

Periodontology is that specialty in dental practice which has to do with the etiology, pathology, and treatment, of diseases occurring in the investing tissues of the teeth, by which is meant the gingiva, alveolar process, cementum, and pericementum. The most common of these, and the one under consideration, is that chronic disease, which, for nearly half a century, has been known as pyorrhea alveolaris. It is a disease as old as civilization. Mention is made of it as existing among the Egyptians more than three thousand years B. C.; also, as a disease, not uncommonly among the early Greeks, Phoenicians, Etruscans, Chinese, and Romans (9, 12). It was usually referred to as "loose teeth," evidently little attention having been given to it until it had progressed to an advanced stage as indicated by the fact that it was referred to as "loose teeth."

[1] The first unit in this series, with a statement of the plan to publish reviews under this general title, was published in the last preceding issue of the Journal of Dental Research (1919, i, p. 525).—(Ed.)

PERIODONTOCLASIA

Ruysch (12), a seventeenth century writer, says "loose teeth" was generally ascribed to scurvy, but expressed the belief that it was caused by the accumulation of tartar. A French writer, in the *Lancet* about 1860, refers to it as a "not uncommon disease of the gums and alveola, hitherto unnamed," which he calls "expulsive gengivitis" (8). About 1845, Riggs, of Hartford, Conn., achieved considerable reputation by calling attention to a disease that caused loosening of the teeth, which he asserted was curable. He gave a demonstration of his treatment at a public clinic in Northampton, Mass., in 1867 (13). This disease was recognized by the dental profession, at that time, as a common one among adults, but was regarded by them as incurable. During Riggs' life-time, and for many years thereafter, this condition was commonly referred to as "Riggs' disease," though this name was not given to it by Riggs himself (10, 25, 27, 28, 29, 34, 39).

In 1877, Rehwinkel referred to the disease, and gave it the name of "pyorrhea alveolaris" (31). It is probable that this name was not original with Rehwinkel but was borrowed by him from some unknown French writer (2, 3, 18). This name, which can logically be applied to it only in the advanced and suppurative stage, has never been wholly satisfactory, and many efforts have been made to find a more appropriate term, but without complete success.

More recently, the American Academy of Periodontology, an organization devoted to the study and practice of periodontia, in an attempt to provide a term more nearly descriptive of the pathology of the disease, has given it the name of *periodontoclasia*, a term which seems destined to take its place in scientific nomenclature, and is the one which will be employed in this article.

Etiology

There have long been three conflicting schools of thought regarding the etiology of periodontoclasia: one regards it as constitutional in origin; another believes it is due to bacterial infection; a third contends it is a local disease, with little or no relation to systemic conditions or to influences outside of the mouth (15).

Those who hold to the "*constitutional theory*" have furnished almost no support for their belief; nothing of an exact nature is known regarding the influence of disease, heredity, diet, etc., upon the causation and progress of periodontoclasia. This is unfortunate, for there are cases which cannot be altogether explained by the theory of local causation and which point to possible systemic complications. The fact that mercury and iodide of potassium may adversely affect the gingivae is conclusive proof that diseases of the periodontium may occur from constitutional causes, or in other words, from poisons that circulate in the blood and have an elective affinity for these tissues. There is accumulating evidence that anomalies of diet may be a considerable factor in its etiology, but no work of a scientific nature has ever been done to support or overthrow this view.

It is a well-known fact that scurvy is a disease which affects the teeth and gums, and is due to what has been termed the "devitalized condition" of certain necessary ingredients of the diet. It is becoming increasingly evident that, in their preparation for absorption, calcium, the phosphates, and, it may be, other salts and substances in food, may become associated or disassociated in such a way that they cannot be absorbed and utilized by the organism. Moreover, it is probable that certain salts in loose association are necessary for the proper activity of the digestive and other enzymes (1). That an unbalanced diet may affect the peridontium, is suggested by the occurrence of scurvy in adults and of Barlow's disease in infants. It is, therefore, not unreasonable to suspect that an ill-balanced diet may also express itself in that form of periodontal disease known as periodontoclasia. The initial results of some investigations that Dr. Percy R. Howe has under way tend to confirm this suspicion.

The "*parasitic theory*" regarding the etiology of periodontoclasia has had its strongest supporters abroad, though its adherents have not been unknown in this country. Miller (26), however, who, in common with others, believed that bacteria were complicating factors, practically proved that there was no causal relationship. Though much study has been given to the subject since the days of Miller, there has never been any evidence to show that there is a specific infective organism; and few, if any, entertain a belief in such an agent at present. Recent investigations (21) of the bacterial flora of nor-

mal mouths, when compared with those in which suppurative periodontoclasia was present, has shown that there is no *qualitative* difference. There is, however, a great *quantitative* difference, due to the more favorable field for bacterial growth presented by the mouth in which periodontal disease is present. Nevertheless, bacteria have been shown to be factors worthy of consideration, inasmuch as they are responsible for certain symptoms and render prognosis more doubtful.

The theory that endameba caused periodontoclasia was first announced in 1914 (4). This belief was based on the fact that Endameba buccalis was found in pyorrheal pockets and could be destroyed by the administration of emetin, which has long been known to be an efficient amebacide. Endameba buccalis was doubtless, in common with bacteria, responsible for certain symptoms, but sustained no causal relationship to the disease. In common with bacteria this organism was subsequently shown to be an inhabitant of *normal* mouths, though it occurs in relatively smaller numbers normally (21).

The advocates of the "*local-disease theory*" have furnished what seems to be convincing proof of the reasonableness of their claims as applied to most cases, in achieving a considerable measure of success in its treatment. The factors in its etiology are divided by them into two groups, primary and secondary (20). The *primary causes* are those that act directly on the tissues involved and have one feature common to all, namely, they are irritative in their nature. These are again subdivided into two classes: (a) those which begin at, and at first are confined to, the gingivae, such as the irritation produced by uncleanliness of the mouth (the most common of these causes); defective contact-points that admit of food impaction; overhanging edges of fillings; ill fitting crowns, bridges, plates, etc.; and (b) those which affect primarily the pericementum through a form of occlusion known as "traumatic" (24).

This type of occlusion, due to a lack of coördination of the inclined planes of opposing teeth when brought into contact in the act of mastication, subject the teeth to an abnormal strain, by which they are driven outside their normal limits of motion. Roentgenographic examinations of tissues subjected to the irritative effects of such occlusion, show thickening of the pericementum and, when long enough continued, rarefaction also in the bony support of such teeth. Loos-

ening is the chief clinical symptom. When such conditions are associated with gingival irritation, there will be found all the elements necessary for the development of periodontoclasia in many instances.

The *secondary causes*, such as abnormal systemic conditions, chemical irritations, etc., are recognized as possibly predisposing rather than as exciting causes. They are not thought, by those who hold to the local theory, to be the important factors in the etiology of periodontoclasia, that those in the primary group are, but are regarded as being worthy of consideration (19).

Pathology

Periodontoclasia is primarily a disease of the investing tissues of the teeth (23). It may be defined as a progressive resorption of the alveolar process and pericementum, with a coincident inflammation of the gingivae and gums, and the formation of pockets about the roots of affected teeth. Clinically, it appears to begin at the gingival border and progresses slowly toward the apex of the root, resulting in the complete destruction of the alveolar process and pericementum, with eventual loss of the teeth involved unless arrested by treatment. Some of the phenomena attending its progress are gingival inflammation; solution of continuity in the floor of the gingival crevice; absorption of the alveolar process; pocket formation; recession of gums; suppurative infection; thermal sensitiveness; separation, elongation, and loosening of teeth. As a rule, these changes make their appearance slowly, years often elapsing between the initial gingival inflammation and final exfoliation of the tooth, depending in a measure upon the nature of the injurious agent, the thickness of the alveolar bone, cleanliness of the mouth, resistance of the patient, etc. The final result of these changes is the formation of a *cul-de-sac* bounded at one point by the extreme limits of bone destruction and at the other by the marginal gingiva. Between these two points there may be a pocket of considerable depth, depending upon the amount of bone loss and gingival recession. Laterally these pockets are bounded, on the one hand, by the overlying soft tissues; on the other, by the cementum with its investment of necrotic pericementum and calculary deposit. Into these pockets, even in their earliest beginnings,

the bacterial flora of the mouth finds its way. These organisms are secondary invaders (21), having no direct etiological relationship to the disease, though they are responsible for certain of its symptoms and may give rise to metastatic infections of the gravest import.

Among early writers little attention was given to its pathology; they refer to the disease as "loose teeth," and seem not to have recognized it in its earlier manifestations.

Treatment

In an effort to arrest the progress of periodontoclasia some form of treatment "to make loose teeth firm" has existed from early times. Pliny (12) recommends "the soaking of two frogs, after having cut off their feet, in a hemina of wine, and the washing of the mouth with the latter." He also recommends the following: "To strengthen unsteady teeth, rinse them with a decoction made by boiling ten frogs in three sextaries of vinegar until the liquor is reduced to one third." Celsus (12) offers the following: "If the gums separate from the teeth, advantage can be derived from keeping vinegar in the mouth, provided it is not too strong." Fauchard (12), writing in 1723, recommended, "rinsing the mouth every morning and also in the evening before going to bed, with a few spoonfuls of one's own urine immediately after it has been emitted. One is to hold it in the mouth for some time and the practice ought to be continued. This remedy is good but undoubtedly not pleasant, except in so far as it procures great relief." These remedies seem to have been directed toward reduction of the symptoms of the disease.

Among modern writers, Riggs (13) seems to have been the first to teach its curability, and to prove his contention by public demonstration of his method of treatment. On June 11, 1869, the Connecticut Valley Dental Association (17) passed a resolution in which it is stated that "the credit of originating and first publicly describing a new treatment for the *cure* of inflammation of the gums and absorption of the alveolar processes, or the so-called 'scurvy of the gums,' is due to Dr. John M. Riggs of Hartford, Conn." This treatment was largely surgical, consisting in a curettage of the pockets, root surfaces, alveolar bone, etc. (32, 33). Though somewhat heroic, as prac-

ticed by Riggs, it seems to have been efficacious and, with certain refinements of technique, is the method employed by the modern periodontist. Whatever theory may be entertained by the present-day students of the subject, all agree that local surgical treatment is of first importance.

Those who believe in its constitutional origin assert that constitutional treatment is also necessary (35), but there is no unanimity of opinion as to what that treatment should be, and none has ever come into general use. The believers in its parasitic origin have advocated the use of vaccines (14), but their use has been practically discontinued as of no value (22). The advocates of the local disease theory have relied upon local treatment, claiming that where this was intelligently employed, all other forms of treatment were superfluous; that where this was not skillfully done, or when attempted in cases clearly beyond all hope of cure, other forms of treatment were of no avail (24).

Local treatment, as practiced by the modern periodontist, consists in the correction of occlusion when occlusal trauma is present (usually by judicious grinding of occlusal surfaces), and in a painstaking curettage of each individual pocket (37). This necessitates the removal not only of all calculary deposits upon the exposed surface of the cementum, but the complete removal also of the necrotic pericementum, permitting thereby physiological contact between the vital cells of the cementum with those of the overlying vascular tissues (30). The cementum must, at the same time, be left smooth, care being exercised not to curette through into the dentin. In certain cases, curettage of the affected alveolar process is also indicated. There are those who advocate dissecting back the gum tissue, with curettage of the cementum and alveolar process, followed by replacement and suturing of the gum-flap into position (40). Others recommend excision of the gum tissue to a plane a little below the extreme limits of bone necrosis and chiseling of the bone down to this level (5). The latter drastic forms of treatment have never come into general favor and are universally condemned by periodontists. More than half a century ago they were characterized by Riggs as "simply barbarous" (33).

When local treatment has been skilfully performed, the results are usually satisfactory. In its early stages the results are all that could

be desired. In advanced and suppurative cases, where the factors which have caused it are recognized and removed (and a careful study of each case is necessary to determine them), the results are also gratifying: suppuration ceases, the tissues resume their health, and the teeth become firm, or, at least, firmer. In some cases and under favorable conditions, there will be a re-deposit of osseous tissue and a reattachment of the vascular tissues, with obliteration of pockets (36).

In the case of septic pulpless teeth, and for vital teeth, also, where the bone has been destroyed nearly to the apex of the root, or between the roots of multi-rooted teeth, the prognosis is usually unfavorable. It will also be unfavorable where surgical treatment has not been skilfully done—health will not be reestablished about teeth on which poor surgery has been practiced. Moreover, success is dependent, in a measure, upon the coöperation of the patient in maintaining a high order of mouth hygiene following treatment, which coöperation is not always obtained. In fact, so many factors enter into the successful treatment of periodontoclasia, such as intelligent diagnosis, ability to discriminate between those cases which are clearly incurable and those which are not, a painstaking and most exacting technique, coöperation of the patient, etc., that the results of treatment in advanced cases will always be more or less problematical. This doubtless explains the diversity of opinion regarding treatment, some declaring it to be an incurable disease, while others again assert with equal positiveness that it can always be cured, if not too long neglected. The essential thing would seem to be early recognition of the disease, combined with skilful treatment.

CONCLUSIONS

It will be evident to anyone at all familiar with the subject that there are many unsolved problems in periodontia. Investigation as to the possible relationship between diseases of the periodontium and certain constitutional diatheses, heredity, diet, etc., is very much needed. The same is true regarding local conditions. Light is needed on the nature of the early pathological changes occurring at the cemento-enamel junction; on the phenomena attending bone resorption; on the modus operandi of calculary deposition; on the microscopic effects of occlusal trauma; on localized circulatory disturbances,

etc. These are problems of the greatest importance to the health and well-being of humanity, and must be solved sooner or later.

Meanwhile, there are some things which seem reasonably well established. It is probably true that periodontoclasia is not, as some seem to think, a disease of modern life. All the evidence at hand points to the fact that it is as old as civilization and may be older (9, 12). It is also a curable disease. Its prognosis, however, will be found to depend in large measure upon the progress which it has made when it first presents for treatment, and the skill with which it is treated. However complex may be the etiology of periodontoclasia, present knowledge points to the fact that, as a rule, *local conditions are the controlling factor*, and that their recognition and removal will invariably be followed by marked improvement or cure. It has been repeatedly shown that, in its treatment, the only method that is really effective is the *surgical or so-called local treatment.* It is probable that, where this is skilfully done and the intelligent coöperation of the patient obtained in maintaining a high order of mouth hygiene, many cases can be permanently cured and all can be improved. Finally: it is a preventable disease, requiring only intelligent coöperation between patient and dentist.

59 West 46th Street

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THE ORIGIN AND EVOLUTION OF THE HUMAN DENTITION

A Palaeontological Review

WILLIAM K. GREGORY

Columbia University and the American Museum of Natural History, New York City

PART I. STAGES OF ASCENT FROM THE SILURIAN FISHES TO THE MAMMALS OF THE AGE OF REPTILES

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I. EARLY STAGES OF VERTEBRATE EVOLUTION, SEEN IN THE FISHES OF THE PALEOZOIC ERA

The later chapters in the evolution of the human dentition can only be understood in the light of the whole story, so it is advisable to begin at the beginning, or as near to the beginning as the palæontological record extends.

The Ostracoderms of the Upper Silurian and Devonian

The problem of the origin of the vertebrates we must necessarily ignore, because the innumerable answers to it cannot be tested by an appeal to the palæontological record. We can, however, begin at a very early stage, represented by the ostracoderms of Silurian and Devonian times, which are on the whole the most primitive of all known chordates. It is true that the modern *Amphioxus* and the cyclostomes have acquired a world-wide reputation as primitive chordates but, in the absence of palæontological evidence, their real status is still unsettled; and, in their present conditions, they teem

with specializations which conceal their primitive characters. The Paleozoic ostracoderms, on the other hand, afford definite information of a pregnathostome stage of evolution which is lower and, as a whole, older, than any other group of vertebrates. Although much excellent material is preserved in the museums of the world, none of these lowly fish-like chordates shows the least evidence of having attained "gill-arch jaws" of the normal vertebrate type. Some of them had a capacious mouth and, in the latest and more specialized ones (*Bothriolepis*, *Pterichthys*), the ossified dermal plates around the slit-like mouth acquired jagged edges and may have functioned in the prehension of food; but no known ostracoderm had either teeth or calcified oral and branchial arches. For the most part they probably fed on small organisms found in the mud on the bottom of the streams in which they lived. Possibly they may have extracted the nutriment from

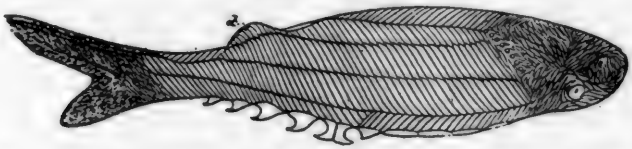

FIG. 1. *Birkenia elegans*, A PRIMITIVE FISH FROM THE UPPER SILURIAN OF SCOTLAND
Illustrating a stage of evolution before the formation of teeth and jaws. Natural size. After Traquair.

the mud by ciliary tracts, as in *Amphioxus* and the larval lamprey. One of them (*Birkenia*) was shaped somewhat like *Amphioxus* and could perhaps dart about freely in the water, but most of them were depressed in form and probably lived on the bottom. None of them had attained the swift-swimming, predatory form, armed with strong teeth, which, there is much evidence to indicate, was the starting-point for the development of vertebrates higher in the scale.

THE DEVONIAN SHARKS

The numerous group of sharks, dating back to the Upper Silurian but well known only in the Devonian and later periods, are with good reason regarded as primitive in their class characters, since they all have the primitive vertebrate ground-plan of the endoskeleton. While most of the known ostracoderms had over-emphasized the exo-

skeleton, the elasmobranchs very early built up an endoskeleton by precipitating calcium salts in the connective tissues and septa, which form a nucleus or core of the endoskeleton. They were active, predatory, fishes and developed further than did the ostracoderms the method of moving by rhythmic contraction of the muscle segments,

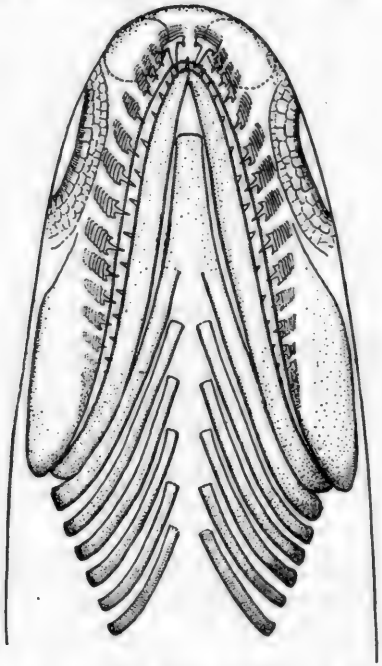

FIG. 2. UNDER-SIDE OF THE HEAD OF *Cladoselache fyleri*, A PRIMITIVE SHARK FROM THE UPPER DEVONIAN OF OHIO

Showing the primary jaws, homologous with the branchial arches, and bearing teeth on the skin inside the mouth. The eyes are surrounded by rows of sclerotic plates, which are homologous with the teeth and with the shagreen denticles of the skin. After Dean.

or myomeres, arranged on either side of the mid-line. The development of the endoskeleton stiffened the median axis against the thrust of the myomeres and made possible the assumption of aggressive habits.

In the earliest known sharks the mouth is supported by cartilaginous jaws of the "gill-arch" type. Even modern sharks retain much

evidence tending to show that the cartilage jaws are serially homologous with the gill arches, and that the primitive jaw muscles for squeezing the upper and lower halves of the oral arch together are serially homologous with the constrictor muscles of the gill arches.

It is well known to all students of odontology that, in typical sharks, the skin all over the body is covered with shagreen denticles, and that the primitive dental lamina of sharks is merely a rolled-up fold of skin bearing the dermal denticles, and carried around onto the inner side of the mouth. The whole surface of the throat is also covered with this denticle-bearing skin, and it is for this reason that in later groups of fishes we often find teeth on the pharyngeal parts of the gill arches.

In this primitive vertebrate stage the primary or cartilage jaws articulate posteriorly with the sides of the primitive cartilaginous brain case and are also supported by the second, or hyoid, arch. The endocranium itself is a complex of the connective tissue surrounding the capsules of the sense organs and the anterior end of the notochord. The denticulate skin covering the whole body represents the dermal skull, the bony sheaths of the jaws, and the scaly areas on the body of the higher fishes.

It is only in respect to the ground-plan, or class characters, that sharks are primitive, because most of the known sharks even in the Devonian are already diversely specialized in the dentition. The primitive shagreen denticles often fused into great dental plates of diverse form, as in many of the rays, adapted for crushing shellfish. The sharks remained primitive, however, in that they never developed sockets for the teeth in the upper and lower jaws.

The Devonian Ganoids and Lung-fishes

The undiscovered links between the ostracoderms and sharks, and between the predecessors of the sharks and the oldest ganoid fishes, may some day be found in the Upper Silurian. At least in the Lower Devonian the primitive ganoid fishes were already established. These exhibit a distinctly higher stage in the evolution of the vertebrates than did the sharks. The teeth are now sharply differentiated from the rest of the exoskeleton and are often set in distinct sockets or

grooves in the derm bones of the jaws; the head skeleton is complex, consisting, first, of an outer mask of derm bones, the histological elements of which are identical with those of the scales, and second, of the inner or endocranium, homologous with the cartilage skull of the shark, but now invaded by bony tissue. So, too, the primary or cartilaginous lower jaw (Meckel's cartilage) has been sheathed in a

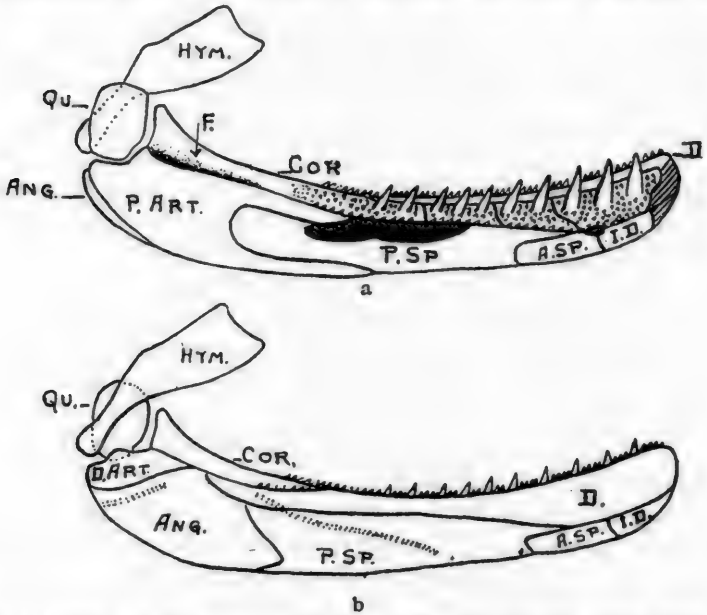

FIG. 3. LOWER JAW OF *Eusthenopteron foordi*, A CROSSOPTERYGIAN GANOID FROM THE UPPER DEVONIAN OF SCAUMENAC BAY, QUEBEC

The primary lower jaw (Meckel's cartilage) is completely covered with derm bones, which are severally homologous with those of the earliest tetrapods. The teeth are of the labyrinthodont type and are limited to the dentary and the coronoid series. After Bryant. Upper figure (a), inner side; lower figure (b), outer side. *F*, mandibular fossa (for the insertion of the jaw muscles); *D*, dentary; *Cor*, coronoid series.

thick coating of dermal bones, and similar derm bones cover the roof of the mouth and the lips, giving rise to external or secondary jaws (premaxilæ, maxillæ), to the vomer and parasphenoid, and to the dentigerous tracts which partly cover the primary upper jaw or ossified pterygoquadrate cartilage.

These earliest ganoids, using the term in its wide sense in allusion to their shiny ganoid scales, include three very distinct groups. The first, or actinopterygian series, of which the fullest palæontological record is known, leads up through long successive ages to the highly

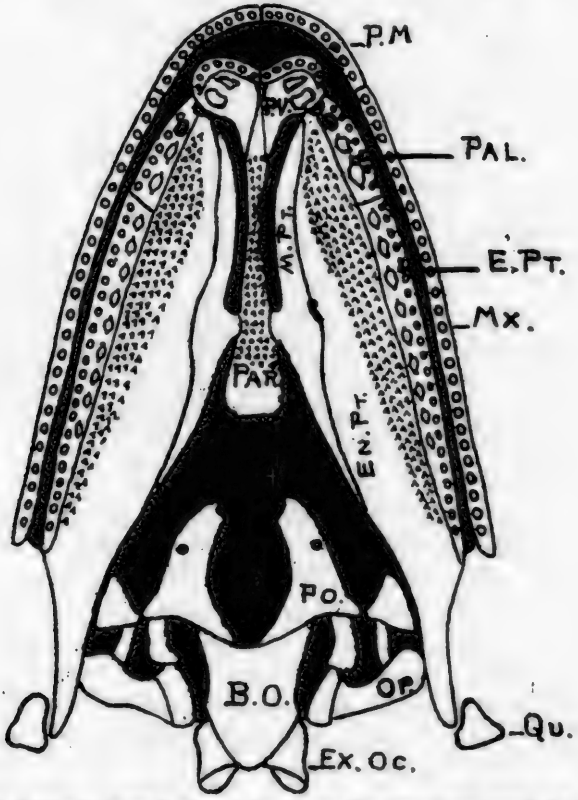

FIG. 4. PALATAL ASPECT OF THE SKULL OF *Eusthenopteron foordi* (CF. *fig. 3*)

Showing the dentigerous tracts, located as follows: (1) on the marginal or secondary jaws, including the premaxillæ and maxillæ; (2) on the primary upper jaws, or palatopterygoids; and (3) on the derm bones beneath the anterior part of the primary brain case, namely, the vomers (prevomers) and parasphenoid. After Bryant.

specialized modern teleosts, including by far the greatest number of existing fishes. In these the locomotor apparatus attains its highest perfection for progression through the water. The tail passes from

the heterocercal, or shark-like, type, to the homocercal, or "fish-tail," type. The primitive scales covering the fin-webs become fused in rows and give rise to the bony dermal rays, which support both the median and paired fins, and form one of the dominant features in the economy of these fishes. The jaws become diversely specialized away from the primitive predatory type, in adaptation to nibbling, grinding, sucking, etc. Very often pharyngeal teeth on the gill arches become of great functional importance.

In wide contrast to the actinopterygian series is the dipnoan group which failed to become progressively specialized except along certain degenerate, eel-like lines. Their modern representatives are equipped with a well-developed lung in addition to their gills, which serves them especially when the pools in which they live either dry up or become deficient in oxygen. The Devonian dipnoans already bore the main characteristics of the group, and very probably likewise were provided with lungs. Although paralleling the amphibians in many respects, they are definitely removed from the ancestral line of the Tetrapoda, or four-footed vertebrates, through the early aberrant specialization of the dentition. This consists chiefly of clusters or aggregations of dental tubercles arranged in two fan-like series on the roof the mouth, opposing a similar series on the inner side of the lower jaw. Histologically, these tubercles are homologous in construction with the teeth and scales of the primitive crossopterygians described below. The apparatus as a whole is primitively adapted for crushing and in modern forms for cutting, but in this group the earliest representatives are less carnivorous in construction than are their modern derivatives. The dermal cranium and the endocranium, as well as the mandibles, are profoundly modified to provide a firm base for these crushing plates.

The dipnoans, as well as certain types of sharks and rays, afford well proved examples of the development of the complex dental apparatus through the concrescence of small tubercles but, as they are definitely out of the line of ancestry of the tetrapods, it would be futile to cite them as evidence for the theory of origin of complex mammalian molar teeth through concrescence of separate teeth.

The second group of ganoids includes the crossopterygians, or lobe-finned series. These parallel the actinopterygians in the development

of dermal fin rays, but never progress so far in building up an efficient homocercal tail. They differ widely from the first series in the structure of the paired fins, which had a more or less elongate fleshy axis in addition to the fringing dermal rays. All the available evidence points to the members of this series (*Osteolepis*, *Megalichthys*, *Eusthenopteron*, etc.) as standing relatively near to the ancestors of the Tetrapoda, or four-footed vertebrates, but here again the connecting links are lacking from the fragmentary geological record.

The group is represented, at the present day, by two more or less degenerate survivors, *Polypterus* and *Calamoichthys* of Africa. In these fishes the "air-bladder" retains traces of the vascular condition which is better developed in the living dipnoans and surviving prim-

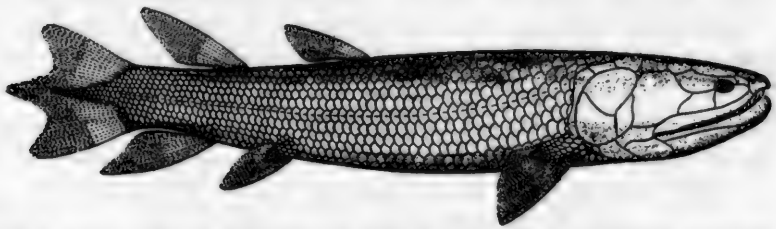

FIG. 5. RESTORATION OF *Eusthenopteron foordi*, A CROSSOPTERYGIAN GANOID FROM THE UPPER DEVONIAN OF SCAUMENAC BAY, QUEBEC

Illustrating the general type of fish from which the land-living vertebrates probably arose. After Bryant.

itive actinopterygians (*Amia*, *Lepidosteus*); that is to say, the "air-bladder" in all the more primitive ganoids probably already functioned to oxygenate the blood and to supplement the function of the gills, because the living dipnoans and some of the living ganoids are, in fact, able to breathe atmospheric air.

II. THE EMERGENCE OF FOUR-FOOTED, AIR-BREATHING VERTEBRATES (PRIMITIVE STEGOCEPHS) IN THE UPPER DEVONIAN AND LOWER CARBONIFEROUS AGES

Perhaps as far back as the middle Devonian some of the crossopterygians became adapted to a periodic drying up of the streams and were able to live by means of their lungs, as are the modern lung-

fishes. In some of them the stout pectoral and pelvic paddles began to be used in crawling, and this was doubtless the initial step in the origin of the paired limbs of land-living vertebrates. Anatomical evidence is very decisive that the pectoral and pelvic limbs of four-footed vertebrates are truly homologous with the pectoral and pelvic paddles of fishes. Some who delight in turning the geological record upside down have argued that fishes have been derived from tetrapods, but this has found scant favor among the majority of anatomists and palæontologists, and recent investigations have practically established at least the common origin of the crossopterygians with the tetrapods.

As a whole the geological and comparative anatomical records show that the great advances have been made through revolutionary changes in the general trend of development, as when the birds arose from the reptiles. The primitive crossopterygians gave rise to the earliest tetrapods (which are first known from footprints in the Upper Devonian of Pennsylvania) through a profound revolution, in which the locomotor apparatus, evolved in earlier stages for progression through the water, had to be largely remodeled for progression on land. The dermal rays of the fins and the hitherto important caudal fin were sacrificed, while the pectoral and pelvic paddles were bent around so as to make a knee-joint and an elbow-joint, and to bring the sides of the paddles in contact with the ground. The five-toed hands and feet of the most primitive amphibians probably grew out from the fleshy stumps of the paired paddles.

The earliest tetrapods still went through an aquatic stage of development with more or less functional gills which are retained in many existing Amphibia; but the loss of the gills in the adult conditioned a marked change in the region of the bony gill-covering, or opercular bones. Hence, in the earliest tetrapods, the true or dermal skull has lost the opercular bones and stops at the posterior end of the primary upper jaw and of the bones that cover it, including the squamosal.

While these profound changes were going on in the elements of the skull, the dentition changed surprisingly little, because the earliest reptiles and amphibians of the Coal Measures and succeeding ages still retained the labyrinthodont teeth which are so characteristic of their crossopterygian predecessors. The elaborate infolding of the

FIG. 6. PALATAL ASPECT OF THE SKULL OF *Eryops megacephalus*, A STEGOCEPHALIAN FROM THE PERMIAN OF TEXAS

The labyrinthodont teeth are, for the most part, indicated by their broken stumps or sockets. They are located chiefly on the marginal bones of the upper jaw, with a few larger teeth on the prevomers, palatines, and ectopterygoids. Amer. Mus. Nat. Hist., no. 4,190.

bases of these teeth apparently served to strengthen their connection with the tough bony skin, as may be seen in the modern garpike. These labyrinthodont teeth are distributed along the margins of the mouth in the premaxilla, maxilla and dentary, and also in some cases in clusters of small tubercles, or in a few large teeth, on the roof of the mouth and on the inner side of the lower jaw. The histological composition of these teeth was homologous with that of the scales and of the skull plates, of the more primitive crossopterygians.

Thus, the primitive amphibians and reptiles, no less than their crossopterygian ancestors, were predatory animals with strong jaws and sharp, more or less laniary, teeth. This predatory type gives rise to a wide adaptive deployment into variously specialized dental types fitted respectively for crushing shelled invertebrates, for an herbivorous diet, for fish catching, etc.

III. THE STEM REPTILES (COTYLOSAURIA) AND THE MAMMAL-LIKE REPTILES (THERAPSIDA) OF THE LATE PALEOZOIC AND EARLY MESOZOIC ERAS

It used to be thought that even the oldest reptiles were extremely different from the contemporary amphibians but, as a result of the intensive investigations of recent years, one "diagnostic" class character after another has given way, and more and more characters in common have been shown to connect the primitive reptilian order Cotylosauria with the amphibian order Temnospondyli. From certain more primitive stegocephs of the Coal Measures (e.g., *Loxomma*, *Pteroplax*) to the stem reptiles of the same period was but a short step, involving chiefly the suppression of the "tadpole" stage of development.

In the Permo-Carboniferous beds of Texas is found a group of reptiles, the Cotylosauria, which, in its ordinal characters, is structurally ancestral to all the higher vertebrates. In these animals the temporal region of the skull is still covered by the dermal skull roof, the inner surface of which covered and perhaps gave attachment to the primitive temporal muscle mass. Most of the known members of this group were for the most part already specialized for feeding on invertebrates but, by analogy with many other cases, it can be predicted that the stem forms were more or less carnivorous.

Carnivorous or predatory habits are likewise characteristic of the pelycosaurs, a contemporaneous group which, in the construction of their temporal region, exhibit a stage following the cotylosaurs. The primitive dermal roof is now perforated on each side and the resultant opening is surrounded by the postorbital, jugal, and squamosal bones,

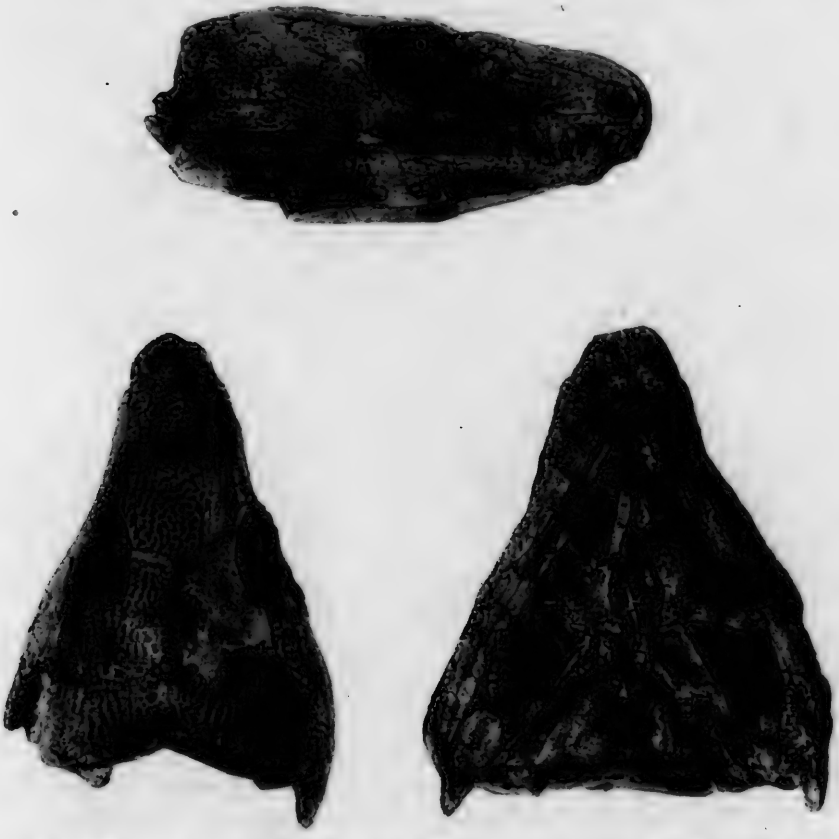

FIG. 7. SKULL OF *Captorhinus angusticeps*, A SMALL COTYLOSAURIAN REPTILE FROM THE PERMIAN OF TEXAS

Showing the unfenestrated roof of the temporal region, the simple teeth, and the effective bracing of the jaws on the palatal side of the skull. Amer. Mus. Nat. Hist., no. 4,334.

and is homologous with the "lateral temporal fenestra" of the existing *Sphenodon*. The teeth, being confined mostly to the margins of the jaws, were embedded in distinct sockets and have lost most of their labyrinthine structure. In some cases there are clusters of crushing teeth on the roof of the mouth.

From some primitive member of the pelycosaur series it is believed the mammal-like reptiles (Therapsida, "Theromorpha" in part)

FIG. 8. SKULL OF *Dimetrodon incisivus*, A LARGE PELYCOSAURIAN REPTILE FROM THE PERMIAN OF TEXAS

Showing especially the carnivorous dentition, the deep compressed skull, the single temporal fenestra, and the mammal-like zygomatic arch, composed chiefly of processes from the jugal and squamosal bones. Amer. Mus. Nat. Hist., no. 4,636.

arose. Numerous and diverse representatives of this order occur in the Permian of South Africa and Russia, and in the Triassic of South Africa. There is a single temporal opening on each side, homologous with the lateral temporal fenestra of the pelycosaurs, bounded below by the stout zygomatic arch, which is composed of the jugal, postorbital, and squamosal. The more primitive types are carnivorous, with laniary teeth embedded in sockets on the margins of the jaws. Aberrant side lines acquired specialized dentitions, some (anomodonts)

losing the teeth entirely, which are functionally replaced by a horny beak. Others, the dinocephalians (plate 1) develop very strong piercing teeth around the front part of the jaws, but have dwindling lateral teeth. Dental clusters on the roof of the mouth are usually small or absent entirely.

Notwithstanding the diverse specializations which exclude many of the Therapsida from the line of mammalian ancestry, the group as a whole shows a strong tendency to assume mammalian characteristics, and some of them come almost to the dividing line between reptiles and mammals. First and most important, they were much more active than their cold-blooded reptilian ancestors. Many of them

FIG. 9. SKULL OF *Ictidopsis elegans*, A SMALL MAMMAL-LIKE REPTILE FROM THE UPPER TRIASSIC OF SOUTH AFRICA

Showing the sub-mammalian characters of the whole skull and dentition. ×3/2. Amer. Mus. Nat. Hist., no. 5,630.

were able to raise the body well off the ground in running, and, in the higher therapsids, the limbs and girdles steadily approach the lower mammalian type. As shown by endocranial casts, the olfactory parts of the brain were submammalian in type and the respiratory system, as indicated especially by the development of a submammalian palate, was also highly progressive. In the almost mammal-like cynodonts there was a sharp regional differentiation of the backbone and ribs into cervical, dorsal, and lumbar, regions, so that it seems quite possible that these animals had the beginning of a mammalian diaphragm.

In the lower members of this series (Gorgonopsia, Therocephalia) the construction both of the upper and lower jaws is of primitive rep-

tilian type but, in the later or Triassic Therapsida (Cynodontia), there is a progressive approach to the mammalian construction both of the dentition and of the jaws. According to Broom (1913), the teeth are now limited to two sets; the molar teeth having no successors and the antemolar teeth being preceded by a deciduous series. Cross sections of the skull of *Sesamodon browni* (Amer. Mus. No. 5,517), made by Dr. Broom and now in the writer's care, show, that in the molar region, at least in the adult, there was but a single set, without successors. The skull and lower jaw of *Diademodon platyrhinus* (Amer. Mus. No. 5,518), described by Broom, is also in the writer's

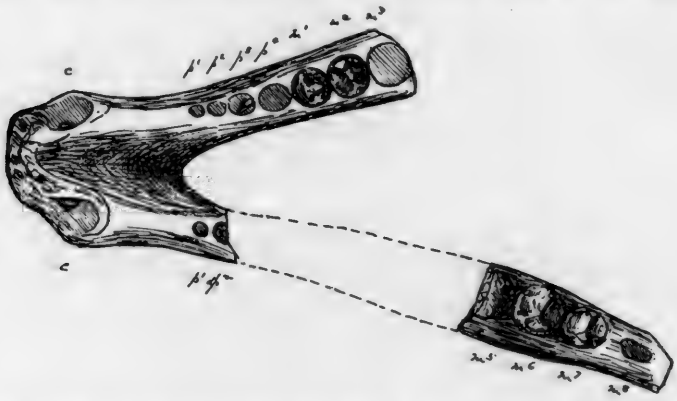

FIG. 10. LOWER JAW OF *Diademodon platyrhinus*, A MAMMAL-LIKE REPTILE FROM THE UPPER TRIASSIC OF SOUTH AFRICA

Showing successional canines and premolar. x 5/4. After Broom

care, and fully validates Broom's statements that the tips of replacing teeth may be seen in the empty alveoli of the upper and lower canines, and of the third lower (deciduous) premolar; also, that there are no replacing teeth beneath the molars; and that, in the imperfect upper jaw, there is "clear evidence of one replacing tooth—the third left incisor." In the type of *Lycognathus ferox* Broom (Amer. Mus. No. 5,538), a section across the skull and lower jaw through the posterior premolar region shows that, in this old animal, there were no teeth beneath the functional set; in other words, the single replacement had taken place. "We may thus safely conclude," writes Dr. Broom

(1913, p. 467), "that as the Cynodont approaches full maturity the incisors, canines and premolars are replaced as in mammals, and as no completely adult specimen has ever shown any trace of a later succession we may conclude as probable that there is only a singel succession." At the lower end of the therapsid series in the order or suborder Dinocephalia, the type specimens of *Taurops macrodon* Broom (Amer. Mus. No. 5,610), and of *Moscognathus whaitsi* (Amer. Mus. No. 5,602), afford a positive demonstration of the following facts: (1) there were two and only two sets of teeth; (2) the three incisors, the canines, and seven or eight of the postcanine teeth, were deciduous and replaced by a second or permanent set; (3) the teeth were arranged in two rows, an outer or deciduous series (exostichos) and an inner or replacing set (endostichos); (4) there is no evidence of replacement of the true molars; (5) the succession of the teeth was vertical, not intercalating. The bearing of these facts is discussed below.

The dentition of cynodonts is differentiated into incisors, canines, premolars and molars, which in certain respects strongly suggest the more primitive mammalian types. Moreover, in this group there is a considerable adaptive radiation in the dentition, paralleling that of the mammals. Beginning with the simple recurved teeth of the gorgonopsians and therocephalians, we have, on the one hand, the compressed, sectorial, teeth of *Cynosuchus*, *Ictidopsis*, *Cynognathus*, *Lycognathus*, *Pachygenelus*, etc., in which the molars have posterolateral cusps suggesting those of the triconodonts among mammals; on the other hand, we have *Diademodon* and its allies, in which the upper molar teeth are wide ovals bearing several cusps, which may be homologous with the cusps of the primitive mammalian molar crown. Watson, indeed, has demonstrated (1913) several structural stages in the evolution of this transversely widened crown of the upper molars of *Diademodon*, indicating its derivation from the compressed sectorial type through the progressive development of a lingual shelf, after the fashion seen in the earlier stages in the evolution of mammalian premolars.

The skull of Cynodonts as a whole is of protomammalian type and the zygomatic arch is especially mammalian, but differs in the retention of the primitive postorbital bone, which is lost in the mammals.

In the lower jaw the dentary finally becomes the predominant element, while the several bones behind the dentary, which are of large size in all typical reptiles, are progressively reduced. The dentary now has a wide ascending ramus of submammalian type, but it has not yet acquired a condyle for the reason that it was still entirely embedded in the temporal muscle and had not yet gained the secondary contact with the squamosal,[1] which gave rise to the mammalian joint between the skull and the lower jaw (cf. Gaupp, 1913).

There is evidence tending to show that the reduced angular of the cynodont jaw was already in contact with the tympanic membrane

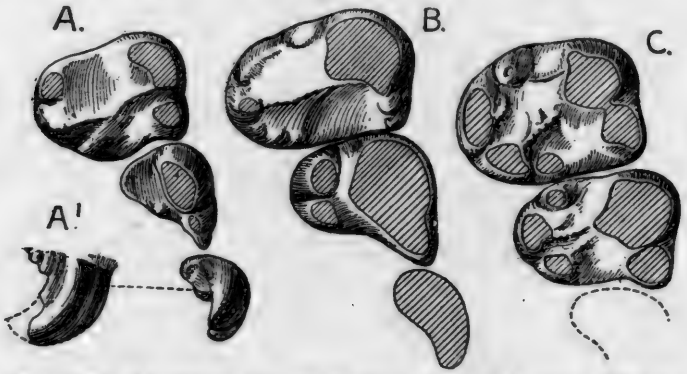

FIG. 11. THE LAST THREE MOLARS OF *Diademodon*. × 3. AFTER WATSON
Showing the apparent mode of formation of the lingual part of the crown through the ingrowth of the basal cingulum.
A, A', Diademodon browni; B, D, entomophonus; C, D, mastacus

(Palmer, Watson), foreshadowing the transformation of these finally minute jaw elements (quadrate, articular, angular) into the accessory auditory ossicles of the mammals. So, too, in the upper jaw the quadrate bone, which in primitive reptiles is very large, is here reduced to relatively small proportions.

Much work has been done in recent years to support Reichert's theory that the incus and malleus of the mammalian middle ear represent respectively the greatly diminished quadrate and articular elements of reptiles. As I first showed in 1910, and as recognized by Gaupp, Watson and Broom, these extinct mammal-like reptiles of

[1] Except *Gomphognathus*. Petronievics: *Proceedings of the Zoological Society* (London), 1919.

FIG. 12. SKULL AND RIGHT UPPER CHEEK TEETH OF *Trirachodon*, A MAMMAL-LIKE REPTILE FROM THE UPPER TRIASSIC OF SOUTH AFRICA. AFTER SEELEY

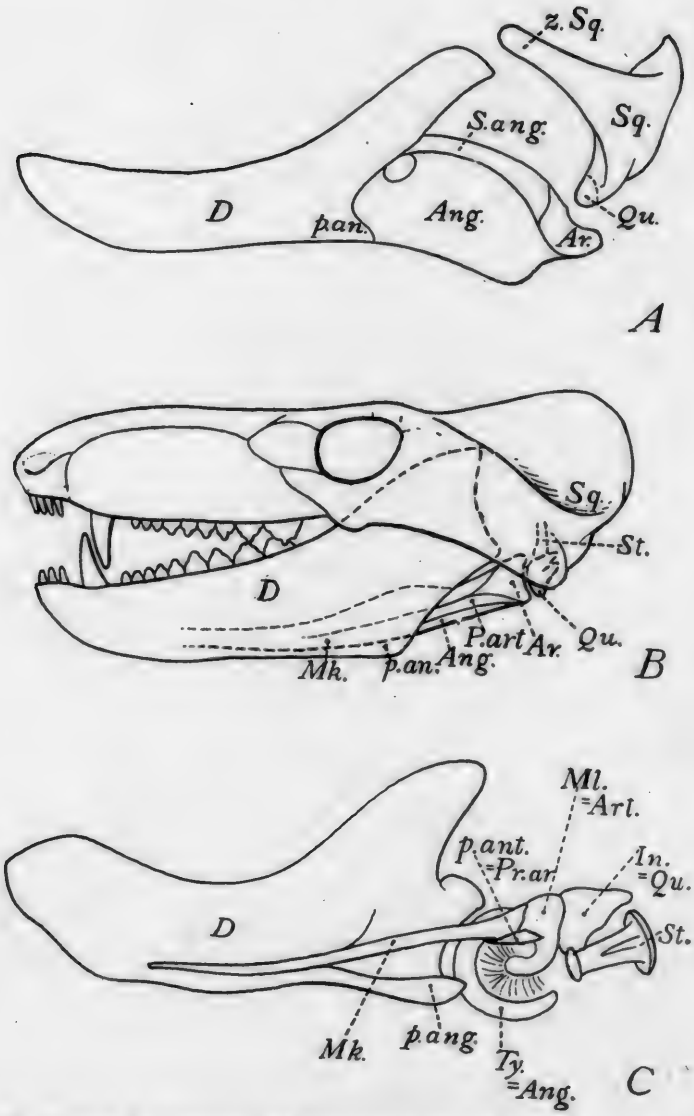

FIG. 13. DIAGRAM ILLUSTRATING THE MORPHOLOGY OF THE LOWER JAW AND OF THE AUDITORY OSSICLES IN MAMMAL-LIKE REPTILES AND MAMMALS

(See legends on page 109)

South Africa afford an almost ideal transitional stage between the primitive reptilian condition, in which the posterior elements functioned chiefly as jaw bones, and the mammalian condition in which they have been entirely surrendered to the middle ear, the jaw functions being restricted to the dentary and the squamosal.

Doubtless objections to this theory will continue to be made by those who are either not familiar at first hand with the anatomy of the therapsid reptiles, or rely on illusory evidence and fortuitous resemblances, such as that furnished by the development of the middle ear in frogs and other groups that are widely removed from the ancestry of the mammals.

The cynodonts thus foreshadow mammalian conditions in the jaws and dentition in the following characters:

(1) The dentition is differentiated into incisors, canines, premolars and molars.

(2) The upper teeth overhang, or bite outside of the lower teeth.

(3) In occlusion the upper and lower teeth alternate, each lower lying between two uppers.

(4) The cynodonts, although closely related in skull structure, in-

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A.—Primitive therapsid condition: a jaw of reptilian type, in which the elements behind the dentary are not reduced.

D, dentary; *p. an*, angular process of dentary, embracing the angular (*Ang*); *S. ang*, surangular; *Ar*, articular; *Qu*, quadrate, largely covered by *Sq*, squamosal; *z. Sq*, zygomatic process of squamosal.

B.—Cynodont condition: jaw of sub-mammalian type; the dentary the predominant element, with a very wide ascending ramus; post-dentary elements reduced, the primary jaw (Articular, Meckel's cartilage) and attached derm bones passing downward and forward, and being received in the fossa on the inner side of the dentary; stapes in contact with quadrate; the latter small and largely covered by the squamosal.

D, dentary; *Mk*, Meckel's cartilage; *p. an*, angular process of dentary; *Ang*, angular; *P. art*, prearticular; *Ar*, articular; *Qu*, quadrate; *St*, stapes; *Sq*, squamosal.

C.—Condition in mammalian embryo (*Macropus*, after Bensley), seen from the inner side: the dentary the sole functional element of the lower jaw; articulation with squamosal by means of a temporo-mandibular joint; elements behind dentary no longer functioning as jaw bones but as accessory auditory elements.

D, dentary; *Mk*, Meckel's cartilage; *p. ang*, angular process; *Ty*, tympanic bone (probably derived from the angular of reptiles); *p. ant*, anterior process of malleus, a derm bone probably derived from the prearticular of reptiles; *Ml*, malleus, probably derived from the articular; *In*, incus, probably derived from the quadrate; *St*, stapes, probably derived from the stapes of reptiles.

clude widely diverse types of dentition, which foreshadow similar series in the mammals. Thus we have:

(a) The primitive, recurved, pointed, teeth of the more ancient cynodonts (*Cynosuchus*).

(b) The compressed, more serrate, recurved, sectorial, teeth of the specialized carnivorous *Cynognathus*.

(c) The transversely expanded oval upper molars of *Diademodon* and its allies, bearing regular transverse crests and low cusps. In this dentition, the small, rounded, lower, crowns fit between two upper crowns, and there is a distinct beginning of the interlocking relations of cusps and spaces that are further developed in the mammals. These transversely oval molar crowns have probably been derived by the lingual inward growth of the compressed crown of the primitive cynodonts (Watson).

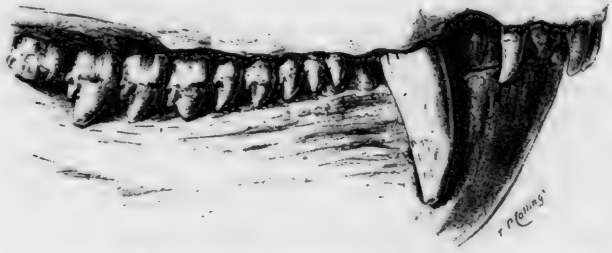


FIG. 14. DENTITION OF *Cynognathus crateronotus*, A CYNODONT FROM THE UPPER TRIASSIC OF SOUTH AFRICA. AFTER SEELEY

Showing the mammal-like differentiation of the dentition. The upper teeth overhang the lower, the lower canine being received into a deep pit in the upper jaw.

(5) The dentition is reduced to two sets, apparently corresponding to the deciduous and permanent series of mammals.

(6) The mandible of the therapsids becomes more and more mammal-like as we ascend toward the cynodonts. The dentary of the latter has a wide ascending ramus, lacking only the condyle of a mammalian jaw. The elements behind the dentary meanwhile dwindle in size and, by a readily understandable progression in the same direction, were probably carried over into the middle ear, especially as there is reason to believe that the posterior process of the angular bone was already attached to the tympanic membrane.

(7) The prearticular part of the primary lower jaw ran downward and forward, and was closely embraced by the mandibular fossa in the dentary, just as in embryonic stages of all orders of mammals, that part of the Meckelian cartilage of mammals, which becomes the anterior process of the malleus, runs downward and forward, and is embraced by the mandibular fossa of the dentary.

Although the cynodonts had many mammalian characters, including two occipital condyles, they were technically reptiles, because the quadrate and articular bones still functioned as jaw bones (at least in part), the dentary was not in contact with the squamosal, the primitive postorbital and prefrontal bones were retained,[2] and the molar teeth were each supported by an undivided root.

IV. THE MESOZOIC MAMMALS

The wide differentiation of the dentition in the therapsid reptiles, and the steady approach of some of them toward mammalian conditions, is in harmony with the fact that, even when the mammals first appear in the geological record, they already exhibit widely diverse types of dentition. Owing to the excessive rarity of Triassic mammalian remains, we lack knowledge of the stages in the evolution of mammals from mammal-like reptiles, and consequently the beginnings of the diverse patterns of the mammalian dentition are lost to view. By Upper Triassic times we find three widely different types of dentition, which may possibly have been derived from different branches of the mammal-like reptiles.

The Protodonta from the Upper Triassic of North Carolina

Family Dromotheriidæ

The first, an extremely primitive type, is represented by two lower jaws from the Upper Triassic of North Carolina, described by Emmons in 1857 and by Osborn in 1888 and 1907. Of these the first, called *Dromotherium sylvestre*, is known only from the left half of a lower jaw about 23 mm. long, seen from the lingual aspect; it is preserved in black shales along with the remains of *Rutiodon*, an extinct reptile also characteristic of the Upper Triassic. The jaw, homologous with the dentary of reptiles, is of carnivorous or insectivorous type. The

[2] See foot-note on page 106.

dental formula is $I_3\,C_1\,P+M_{10}(P_{?3}M_{?7})$. The three pointed erect incisors and the single large canine are separated from each other by large diastemata, and increase regularly in size and in height from the first incisor to the canine. Between the canine and the premolars there is a wide diastema, which indicates the existence of a large upper canine. The three premolars, as figured by Osborn, are

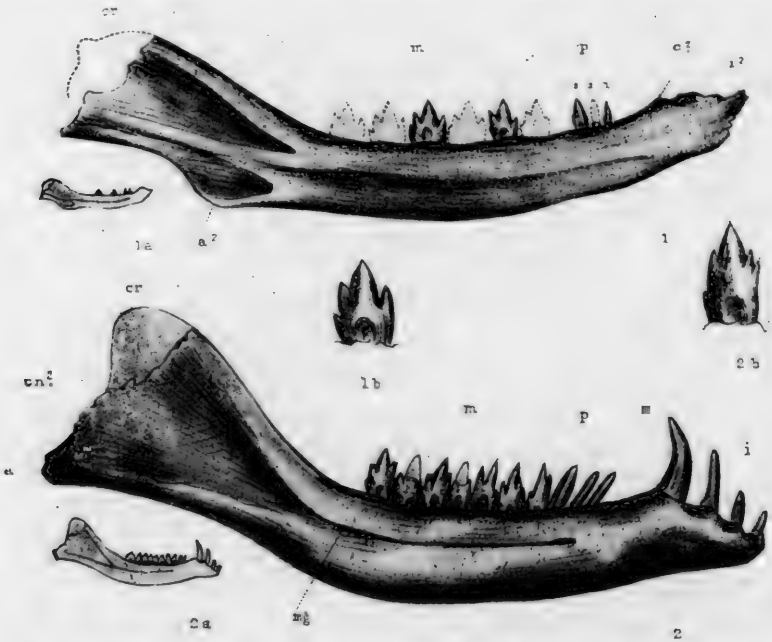


FIG. 15. LOWER JAWS OF *Dromotherium* (2) AND OF *Microconodon* (1), PROTODONT MAMMALS FROM THE UPPER TRIASSIC OF NORTH CAROLINA. AFTER OSBORN

1.—*Microconodon tenuirostris:* outer surface of right half of mandible, greatly enlarged. *1b*, the fourth or fifth molar; much enlarged. 2.—*Dromotherium sylvestre:* inner surface of left half of mandible, greatly enlarged. *2a*, the same; natural size. *2b*, the second molar; much enlarged.

styloid and forwardly inclined. The whole arrangement of the incisors, canines, and anterior premolars, is strongly suggestive of the conditions in the cynodonts, and implies a pronounced overbite of the upper incisors and canines. The chief difference from the cynodonts is the apparent lack of a chin, which is quite deep in that group.

The seven molars are compressed, with two roots one behind the other, the space between the roots extending well above the level of the alveolar border. Each molar culminates above in a compressed, pointed cusp, on the anterior slope of which a second similar cusp points upward and somewhat forward. On the posterior slope there is a third cusp which, in the third molar, is relatively large, but in the posterior molars is smaller, and comes off at a lower level than the anterior cusp. The fifth molar, as figured, has a minute posterior basal spur, suggesting an incipient heel or talonid. Thus, the molars, as seen from above, would appear as compressed, pointed ovals, with a central large tip, and one anterior and one posterior smaller cusp, and sometimes a minute posterior basal spur. Although the molar teeth of this jaw are somewhat like those of *Tribolodon* and other cynodonts, they differ in having two roots instead of one. The mandible is seen from the inner side, and the surface of the dentary is deeply scored by a longitudinal "mylohyoid" groove, which is probably the fossa for Meckel's cartilage, the primary lower jaw. The mandible is curved below as in the primitive cynodonts, and the ascending ramus slopes upward at an unusually low angle, which is more like that of a cynodont than like that of a typical mammal. The condylar process, although imperfectly preserved, was apparently present, that is, the secondary or mammalian contact between the dentary and the squamosal was already established. There is no trace of an angular process on the dentary.

It was long held that the mammalian nature of this jaw was decisively shown by the fact that it consists of a single piece, whereas reptilian jaws, it was said, consist of many pieces. This argument is by no means conclusive, because the reptilian dentary consists also of only a single piece; and the cynodont dentary is, in many ways, like that of *Dromotherium*, which evidently represents the dentary alone, while the elements behind the dentary, if present, might have become separated from it. But, if the condylar process is correctly represented, it shows that there was a contact between the dentary and the squamosal, and therefore the animal is, by definition,[3] a mammal. Moreover, the cynodont molars are supported by a single root while the *Dromotherium* molars have two roots. Both of these

[3] See the foot-note on page 106.

may well be progressive characters derived from conditions in the cynodonts. The vertical position of the incisors and canines is also reminiscent of that group. The dental formula according to Osborn's figure ($I_{\overline{3}}\ C_{\overline{1}}\ P_{\overline{?3}}\ M_{\overline{?7}}$) differs somewhat from those of Cynodonts ($I_{\overline{4}}\ C_{\overline{1}}\ P+M_{\overline{8-12}}$).

From the same Upper Triassic beds of North Carolina is a second and somewhat similar jaw, the *Microconodon tenuirostris* of Osborn. This resembles the jaw of *Dromotherium* in general characters, but the molars, so far as preserved, approach the triconodont type, that is, the central cusp is lower and larger, and the anterior and posterior cusps are relatively higher up on the crown. The premolars also are lower and less styloid; and the posterior premolar, as figured, has an incipient division into anterior and posterior roots. The ascending ramus slopes backward at an even lower angle than in *Dromotherium* and there is a low angular process on the inferior border. The condyle is not preserved, but the flare of the lower border of the ascending ramus suggests that a condyle was present. *Microconodon* thus apparently represents a slightly more advanced stage than *Dromotherium*, pointing toward the more primitive triconodonts of a later age.

Dromotherium and *Microconodon*, occurring together in the Upper Triassic, are possibly a little later in age than the cynodonts, but are structurally intermediate between that group and the triconodonts of the Jurassic, and tend, so far as they go, to show that the latter have been derived from the former.

Karoomys, a Fore-runner of the Trituberculata from the Upper Triassic of South Africa

The second main type of Upper Triassic mammals is represented by *Karoomys browni* of Broom (1902), known from a small jaw about 20 mm. long, from the red sandstone of the Karoo series of South Africa, and assigned by Broom (1909) to the *Cynognathus* beds of Upper Triassic age. Only a single imperfectly preserved tooth remains, perhaps a part of the canine. The jaw has a mammalian look in the presence of a low condyle, a distinct corono-condylar notch and a small angular process. The condyle is only a little above the level of the alveolar border, as in many Mesozoic mammals; the angular process is, however, much larger than that of the cynodont *Dia-*

demodon. The ascending ramus rises at a very low angle, as it does in the cynodonts and in *Dromotherium* and *Microconodon*. The jaw is shorter than that of *Dromotherium* and of most of the Jurassic mammals except *Achyrodon* but, owing to the lack of teeth, its systematic position cannot be precisely determined. The nearest resemblance of the posterior part is perhaps with the Upper Jurassic *Diplocynodon*, as suggested by Broom. *Karoomys* thus supplies another item of evidence tending to connect the mammals with the mammal-like reptiles, and it may represent the fore-runners of the Trituberculata or "tritubercular" Jurassic mammals.

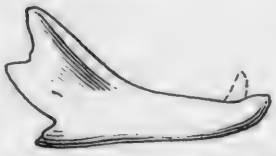


FIG. 16. LOWER JAW OF *Karoomys browni*, A SMALL MAMMAL FROM THE UPPER TRIASSIC OF SOUTH AFRICA. ×1. AFTER BROOM

MULTITUBERCULATES FROM THE UPPER TRIASSIC OF ENGLAND AND GERMANY

Family **Plagiaulacidæ**

The third and by far the most specialized group of the Upper Triassic mammals is known from a few minute teeth from the Rhaetic formations, or Upper Triassic, of Great Britain and Germany, which are the type specimens of *Microlestes antiquus* Plieninger, *Microlestes moorei* Owen, and *M. rhæticus* (Dawkins). These apparently are early, but already specialized, members of the order Multituberculata. In the typical members of this order, the dentition is of the highly specialized "diprotodont" type, with a medial pair of enlarged lower incisors; high, compressed, grooved, fourth, lower premolars; and low, crowned, multituberculate molars.

The *Microlestes antiquus* molar, in crown-view, is oval and compressed, with a long, narrow, central fossa, surrounded by lateral and medial rows of irregular cusps. This molar belongs in the lower jaw and is supported by two large fangs or roots arranged anteroposte-

riorly, and showing a wide space between them. The outer margin of the crown bears three tubercles of regularly increasing size, of which the first at the anterior end is the largest. The lingual border bears a single high anterior apex, the posterior slope of which bears a low cusp.

Microlestes moorei consists of several molars of somewhat varying character. One of them (Owen, 1871; *plate I, figs. 1–3*), supposed to be an upper molar, consists of a large, sub-oval, central basin, bordered by a nearly continuous rim which is sub-divided into three large cusps on one side, but barely divided into small cusps on the opposite side. This tooth had four roots arranged in pairs on opposite sides.

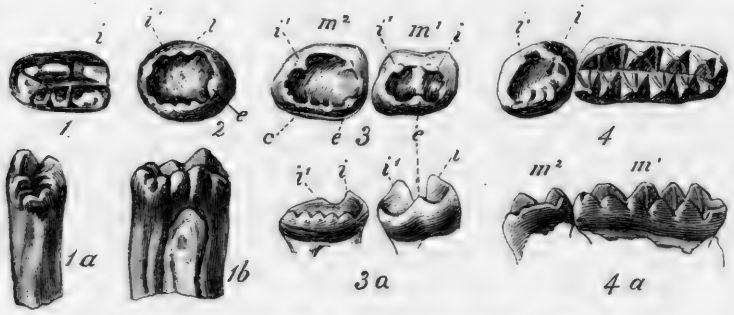


FIG. 17. LOWER MOLARS OF MULTITUBERCULATES. AFTER OSBORN

1.—*Microlestes antiquus*, crown view. *1a*, posterior face; *1b*, external face. All greatly enlarged. *2c.*—*Microlestes* (*Plagiaulax*) *moorei*, crown view. 3.—*Plagiaulax minor*, crown view. *3a*, external face; ×6½. 4.—*Ptilodus trovessartianus*, crown view. *4a*, external face. i, i^1, internal tubercles, e, e^1, external tubercles.

A lower molar of this species (Owen, *plate I, fig. 6*) has a more elongate oval crown bordered by low cusps. In a third specimen the crown is considerably elongated anteroposteriorly, but not so much as in *M. antiquus*. In each case there are a number of smaller cusps on one side and three larger cusps on the opposite side.

The type of *Microlestes rhæticus* (cf. Owen, 1871, *plate I, fig. 16*) is a lower tooth with two large roots, somewhat like those of one of the *M. moorei* molars, and a compressed crown bearing numerous low cusps on one margin. Owen and Falconer recognized its resemblance to the compressed and grooved lower premolar of some of the smaller kangaroos, but in their times it was not realized that such resemblances

in single teeth are often produced by convergent evolution in widely different orders.

A comparison of the lower molars of *Microlestes* with those of the Upper Jurassic genus *Plagiaulax* supports the conclusion of Falconer and of Osborn, that *Microlestes* belongs in the order Multituberculata or Allotheria. Thus, we are confronted with the apparent anomaly that one of the most specialized of mammalian dentitions is also one of the oldest, so far as the geological record is yet known; also that, even at this exceedingly early date, the multituberculate dentition was widely different from the protodont type.

Pachygeneleus, a possible ancestor of the Multituberculates from the Stormberg (Upper Triassic) of South Africa

Numerous guesses have been made as to the origin of the multituberculate dentition. In 1910 I suggested, in a very tentative way, that it might have been derived from the primitive triconodont type, partly through the upgrowth of the basal cingulum forming a second row of cusps. But I also emphasized the extreme antiquity of the multituberculates, and considered the possibility that the order might have been derived independently from the mammal-like reptiles. Professor Bolk has also hypothetically derived the multituberculate molar from the triconodont type as a result of his peculiar theory of the origin of mammalian teeth. Until recently none of the mammal-like reptiles have afforded much evidence as to the possible mode of origin of the multituberculate dentition, but in 1913 D. M. S. Watson described the lower jaw of a new 'Cynodont' from the Stormberg (Upper Triassic) of South Africa, named *Pachygeneleus monuse* which may possibly give the long sought clue. In this animal the medial incisor, i_1, is described as "a large tooth of oval section, which appears to be somewhat procumbent and lies close up to the symphysis. I_2 is a considerably smaller tooth, also of oval section, which lies close behind and outside i_1. The canine is a large tooth whose root, the only part preserved, is of oval section. It seems to have pointed directly upwards, and immediately follows i_2. Behind the canine is a long diastema, which is followed by a series of cheek teeth, six of which are preserved before the fracture which terminates the specimen."

Although the cheek teeth are described as single rooted, the figure suggests the presence of a vertical depression on the inner side which, if further deepened, would tend to divide the single root into anterior and posterior moieties. The molars are narrow from side to side. The crown of the fifth is described as "of an irregular oval shape, widest in front, where it is about three-quarters of its length. There are four cusps arranged longitudinally and forming the outer side of the tooth; the summits of the anterior three of these are broken, but it is certain that the first was much the largest and that they gradually

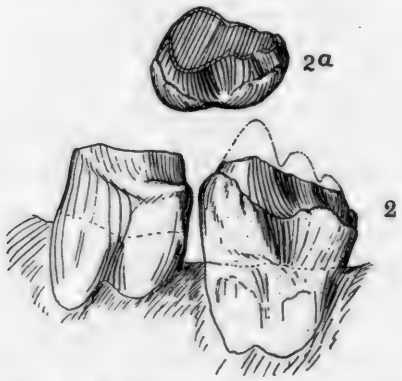


FIG. 18. LOWER MOLARS OF *Pachygeneleus monus*, A 'CYNODONT' FROM THE UPPER TRIASSIC OF SOUTH AFRICA, SHOWING CHARACTERS WHICH MAY BE EXPECTED IN A STRUCTURAL ANCESTOR OF THE MULTITUBERCULATES. ×8. AFTER WATSON

2.—Inner aspect of M_4, M_5. 2a, crown view of fifth molar.

declined in size and height to the fourth." "On the inner side," continues the describer, "is a strong cingulum, whose position will best be understood from the figures. This shows a very faint crimping, as if in the descendants of our animal it might have developed cusps."

This interesting specimen then foreshadows the multituberculate dentition in the following characters:

(1) There is a decided tendency for the lower front teeth, or some of them, to become procumbent.

(2) There is already developed a long postcanine diastema.

(3) The cheek teeth are narrow from side to side and the crowns are of "an irregular oval shape," with a row of four cusps arranged longitudinally and forming the outer side of the tooth, the first being the largest; while on the inner side is a strong cingulum already faintly crimped, "as if in the descendants of our animal it might have developed cusps."

Possibly Dr. Watson had the molar of *Microlestes antiquus* in mind when writing this description but was too discreet to mention it, in view of the well known tricks of convergent evolution. But the fact is that the multituberculates are evidently too highly specialized to be derived from any other *known* order of Mesozoic mammals. On the other hand, the skull structure of one of the later multituberculates shows that they were true mammals related either to the monotremes or to the marsupials, according to different authorities; hence they must at least have arisen from some family of mammal-like reptiles which was closely related to the direct ancestors of the later mammals. Although *Pachygeneleus* itself probably comes a little too late in geological time to be the immediate ancestor of the multituberculates, it shows us a structural stage through which such ancestors must have passed, as we may infer from several similar cases among later mammals with more or less multituberculate-like features of the dentition. The development of procumbent "diprotodont" front teeth, and of a long diastema, has often preceded the reduction or loss of the upper canines, and was in harmony with the development of cheek teeth, with two rows of longitudinally arranged cusps adapted finally for crushing fruits and seeds.

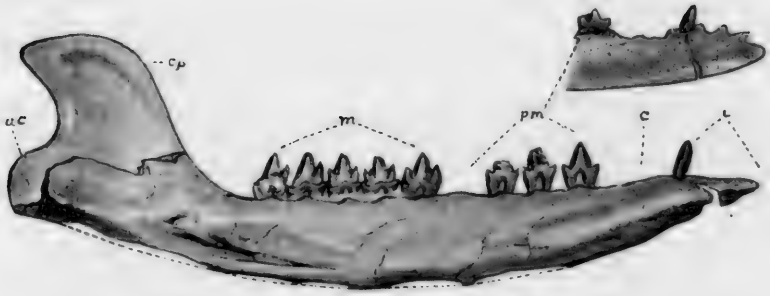
The Mammals of the Stonesfield Slate (Lower Jurassic)

The next vista of Mesozoic mammalian life is afforded by the fauna of the Stonesfield Slate of England, of Oölitic or Lower Jurassic age. This assemblage, as described by Owen (1871), Osborn (1888) and Goodrich (1894), includes but four genera, two of them (*Amphilestes*, *Phascolotherium*) probably representing the descendants of the Protodonta; the third (*Amphitherium*) representing an extremely primitive stage of the Tituberculata; and the fourth (*Stereognathus*), of very uncertain affinities, possibly allied with the Multituberculata.

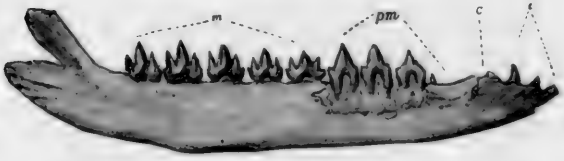
ORDER TRICONODONTA

Family Triconodontidæ

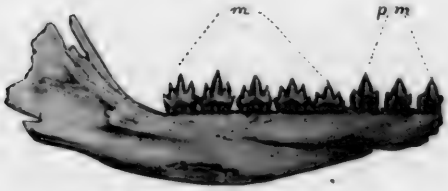
The primitive genus *Amphilestes* is of interest because it tends to connect the Order Triconodonta with the Order Protodonta and to indicate the mode of derivation of the triconodont dentition. The minute jaw of *Amphilestes Broderipii*, some 26 mm. in length, as in so many of these primitive mammals, is long and slender with a curved lower border, a low condyle near the level of the alveolar margin, and a wide coronoid process. The premolars and molars are compressed, each having two well separated roots. The four premolars have high pointed apices and incipient talonid spurs. The molars represent a distinct advance upon the above-described *Microconodon* type, as the anterior and posterior cusps are stouter, and the main central apex is wider anteroposteriorly. A strong, internal, basal cingulum appears, which is produced both in front and in the rear beyond the base of the anterior and posterior cusps. It also rises in the middle opposite the base of the central cusp. The presence of an internal cingulum has been noted above (p. 118) in the cynodont *Pachygeneleus*. It was rapidly developed to extremes in the multituberculates but, in the order Triconodonta, it did not give rise to a second series of cusps parallel to the buccal series. Its origin is obscure, but neither the Triconodonta nor any other order of Mesozoic mammals give evidence for Prof. Bolk's view that the basal cingulum represents a "deutomere," arising from the fusion of a second tooth-germ, lingual to the first. The basal cingulum is often associated with the roots rather than with the summit of the tooth, at least in early stages of evolution. The inner side of the *Amphilestes* jaw is grooved, as in other Mesozoic mammals, perhaps for the remnant of the Meckelian cartilage. Apparently, the angular region is strongly inflected, as it is in other triconodonts, and the condyle is extremely low, in line with the alveolar border. The latter fact indicates that the alveolar process (maxilla) of the upper jaw was vertically shallow and not depressed below the level of the brain case; in other words, that the basifacial and basicranial axes were nearly continuous.



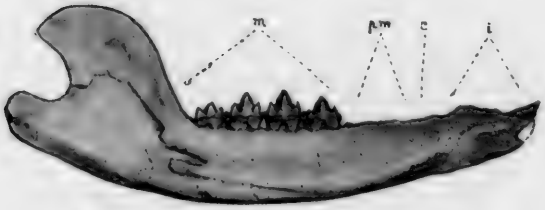
Amphilestes Broderipii [York Mus.].



A. Broderipii [Oxford Mus.].



A. Broderipii [Oxford Mus.].



Phascolotherium Bucklandi [Oxford Mus.].

FIG. 19. LOWER JAWS OF TRICONODONTS FROM THE STONESFIELD SLATE (LOWER JURASSIC). ×4. AFTER GOODRICH

In *Phascolotherium Bucklandi*, the second triconodont from the Stonesfield Slate, the jaw is larger (35 mm. long) and stouter, and the molars have somewhat lower crowns, each with a lower central cusp and better (relatively) developed anterior and posterior cusps. There is a strong internal cingulum, which projects at the anterior and posterior ends of the tooth. This cingulum is clearly associated with the alveolar portion of the tooth, rather than with the coronal part.

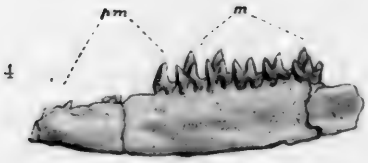
The posterior part of the lower jaw is devoid of an angular process and is strongly inflected, while the groove for Meckel's cartilage is well defined. There are three or perhaps four small and slightly procumbent lower incisors, an erect canine and perhaps seven postcanine teeth. The premolars, as figured, are much like the molars, only smaller. Possibly, some of the submolariform premolars may belong in the deciduous series.

The structural series *Dromotherium*, *Microconodon*, *Amphilestes*, *Phascolotherium*, seems to be tending toward the triconodonts of a later horizon. Osborn has in fact regarded *Amphilestes* and *Phascolotherium* as ancestral to *Triconodon*, with which they agree in the general form of the jaw, inflection of the angle, and ordinal characters of the molars. They differ from *Triconodon* and its allies in the presumably much more primitive construction of the molars. They differ in many characters from the multituberculates and, although more primitive, are probably not ancestral to that group. From *Amphitherium* and the other Tituberculata they differ especially in the form of the jaw and in the construction of the molars, as will presently be shown. There is nothing definite to connect them as ancestors with any of the existing insectivores and carnivorous marsupials, or with any of the orders of placental mammals. They represent an early experiment in evolving a carnivorous type of mammalian dentition, remotely like that of certain existing seals with "triconodont" molars but of comparatively minute size. As being considerably older geologically and also much more primitive than *Triconodon*, they deserve far more attention than they have received, especially from those opponents of the Cope-Osborn "theory of tuberculy" who assume the molar pattern of *Triconodon* as the basis for rival hypotheses concerning the origin of complex mammalian molars.

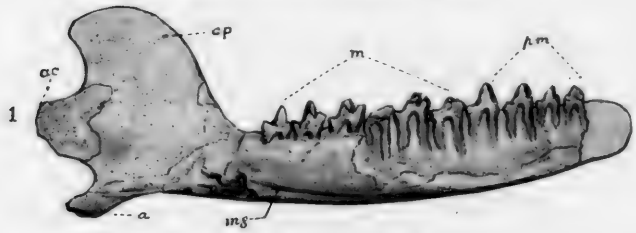
ORDER TRITUBERCULATA

Family Amphitheriidæ

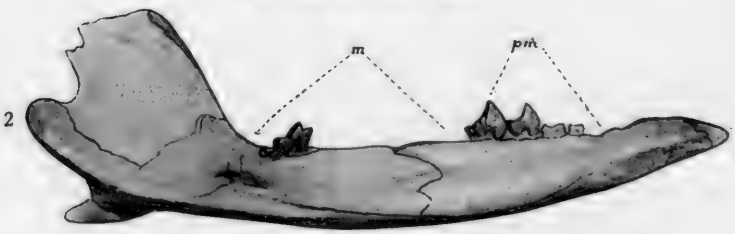
The most important mammal in the Stonesfield Slate fauna, or indeed in the whole Mesozoic history, is *Amphitherium*, since this genus represents the oldest and most primitive form of the "tritubercular" dentition. Known from several lower jaws, the dental formula as given by Goodrich is $I_4\ C_1\ PM_5\ M_6$. It will be noted that this agrees with modern marsupials not only in the number of incisors, but also in the fact that the post-canine teeth (eleven in number) are much more numerous than in either placentals or marsupials of later ages. The relatively high number of post-canine teeth is thus characteristic both of the earliest triconodonts and of the primitive trituberculates, while the reduced number, seven, in typical marsupials and placentals, in all probability, has arisen through the loss of some of the posterior teeth, concomitant with an increase in the anteroposterior diameter of the remaining teeth. The *Amphitherium* jaw differs widely from the specialized marsupial and triconodont types in having a well developed and distinct angular process, as in primitive placental mammals. The areas for the temporal and masseter muscles on the outside of the jaw are clearly indicated, and likewise suggest the condition in primitive placentals. The very distinct and pedunculate condyle is raised well above the level of the alveolar border, so that the maxilla was probably deeper and the face more bent upon the cranium than in contemporary triconodonts. The coronoid process is wide, but ascends at a sharper angle than in the triconodonts and protodonts. The small incisor teeth are gently procumbent, as in insectivorous mammals. The canine appears to have two roots homologous with the two main roots of the premolars and molars. The premolars increase in size posteriorly. They have a compressed conical crown with a steeper anterior edge which appears to be deflected inward toward the base, and a more sloping posterior edge which runs into an incipient basal talonid. There are no indications of paraconids and metaconids in the lower premolars. In the true molars the main cusp on the buccal side is evidently homologous with the single tip of the molars, and, as in all primitive mammals, there is no doubt that the protoconids of the



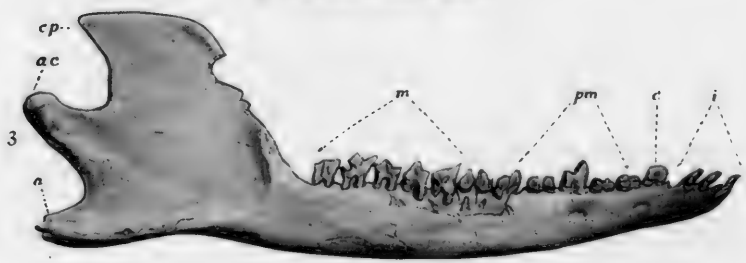
Amphitherium Prevostii [Brit. Mus.].



A. Prevostii [Oxford Mus.].



A. Prevostii [Oxford Mus.].



A. Oweni [Oxford Mus.].

FIG. 20. LOWER JAWS OF AMPHITHERIUM FROM THE STONESFIELD SLATE (LOWER JURASSIC)

Showing the most ancient and primitive known tritubercular lower molars, with asymmetrical trigonids and low incipient talonids. ×4. After Goodrich.

1, 2 —Inner view of left mandibular ramus. 3.—Outer view of right ramus; the outer sides of the molars, including the protoconids, have been broken off. 4.—Inner view of right ramus, showing all three cusps of the first, second and fifth molars; in the third and fourth, the protoconids have been broken off or are hidden in the matrix.

lower molars are serially homologous with the tips of the premolars. The inner side of the molars bears three cusps: (1) anteriorly, a well-developed paraconid directed upward and forward; (2) a metaconid, which is placed almost directly internal to the posterior slope of the protoconid, its tip pointing upward, on a lower level than the tip of the protoconid and level with the tip of the paraconid; and (3) a slight basal elevation on the lingual side hardly deserving to be called a distinct cusp, but representing the beginning of the talonid, or posterior heel, of future tritubercular teeth.

As thus described, *Amphitherium* has an extremely primitive pattern of the lower premolars and molars, archetypal to those of primitive placental mammals as well as of the polyprotodont marsupials.

Both the dentition and the general form of the jaw of this oldest and most primitive tritubercular mammal are in wide contrast to those of the contemporary Triconodonta, and may possibly indicate an entirely separate derivation from the mammal-like reptiles. Nevertheless, there are certain important characters in common to these two orders, as follows: (1) the presence of two main anterior and posterior roots, separated by conspicuous interspaces, on all the premolars and molars, a character distinctly mammalian and barely suggested or not found in mammal-like reptiles; (2) the obvious similarity of the compressed premolar crowns and of their protoconids in both orders; (3) the differentiation of the teeth into incisors, canines, premolars and molars; (4) the low position of the mandibular condyle, the great width of the ascending ramus, the prominence of the Meckelian groove, and the length and slenderness of the horizontal ramus.

While the lower molars of *Amphitherium* are unquestionably of the primitive tritubercular type, which thus appears for the first time in geological history, and while they are thus of great interest as being structurally archetypal to the more advanced stages of later epochs, yet this genus in itself furnishes but little evidence on the mode of origin of the tritubercular ground-plan. The three cusps on the inner side of the lower-molar crown, that is, the paraconid, the metaconid, and the low entoconid, or internal tip of the incipient talonid, might have grown out of the three similarly situated projections of

the internal cingulum of the lower molars of the triconodont genera *Amphilestes* and *Phascolotherium*, but we have no convincing proof that they did so arise.

An especially significant feature of *Amphitherium* is the sharp contrast between the premolars and molars, the former lacking even a suggestion of the para- and metaconids. This contrast is more emphatic in this most ancient trituberculate genus than in the mammals of later epochs, in which the premolars tend to assume the molar pattern; so that, finally, there is a gradual passage from the anterior toward the posterior premolars, which eventually become fully molariform.

In the successors of *Amphitherium*, from the Purbeck beds, there were two sets of antemolar teeth corresponding to the deciduous and permanent series of later mammals. As the molars were not replaced the initial difference between the premolars and molars may somehow be associated with the replacement of the premolars and with the probable fact that the molars are homologous with the first or deciduous series of premolars, and that the post-deciduous molars were suppressed far back in geological time, as we have already seen to be the case in the Triassic cynodonts.

In conclusion, it is certain, from the evidence afforded by *Amphitherium*, that the primitive "tritubercular" type of molar was established as far back as the Lower Jurassic—that at that time the lower-molar crown consisted of a normal "trigonid," with a high buccally placed apex (protoconid) and a basal posterior spur or incipient talonid. The "protoconids" of the molars were evidently homologous with the compressed tips of the premolars, which lacked the para- and metaconids, but already possessed incipient talonid spurs.

Although the upper teeth of *Amphitherium* are unknown, by application of well-founded principles gained from the study of occlusal relations between the upper and lower teeth of many other mammals, it is safe to make the following inferences concerning them:

(1) The upper premolars had simple compressed apices with a low internal extension.

(2) Each upper premolar was supported by two main roots.

(3) The upper molar crowns were unevenly trigonal with high, lingually placed apices, fitting between the trigonids of the lower

molars. The triangular interdental spaces between the upper molars received the trigonids of the lower molars.

(4) The internal apices of the upper molars did not fit into the basins of the talonids as do the similarly placed but not homologous "protocones" of later mammals, for the ample reason that the talonids had not yet acquired basins or fossæ, except in an incipient degree.

(5) The internal apex of each upper molar probably, however, bore a low anterointernal basal rim, the product of the basal cingulum and the probable forerunner of the future "protocone," which articulated with the incipient talonid of the lower molars.

Thus, in *Amphitherium* of the Lower Jurassic, we have fully established the following relations which are the starting point for the more complex conditions of later types:

(1) The premolars of the adult are more simple than the molars and belong to the second or replacing series.

(2) The molars are trigonal, with the primitive apices on the lingual side in the upper teeth and on the buccal side in the lower teeth.

(3) The upper molars are received in the interdental spaces on the buccal side of the lower teeth, while the lower molars are received in the interdental spaces on the lingual side of the upper teeth.

ORDER MULTITUBERCULATA?

Stereognathus

The most puzzling member of the Stonesfield Slate formation is the genus *Stereognathus*, known from a fragment of a lower jaw. The preserved molars exhibit two rows of more or less V-shaped cusps. The affinities of this animal are quite uncertain, at least it has no known bearing on the evolution of the tritubercular type except to emphasize the wide differences in molar patterns which had been evolved as far back as the Lower Jurassic.

The South African Mammal Tritylodon (Lower Jurassic)

ORDER MULTITUBERCULATA?

Family Tritylodontidæ

In the summit of the Karoo series in South Africa, and in a horizon which Broom assigns to the Lower Jurassic, was found the skull of *Tritylodon longævus*. Owen regarded this as a mammal, but Seeley held that it was a modified cynodont reptile. An examination of the original skull by Broom led him, in 1910, to support Owen's opinion and to assign *Tritylodon* to the order Multituberculata. Its dentition is of the highly specialized rodent-like type, with a pair of enlarged pointed incisors, a wide diastema, and a row of seven molars with quadrate crowns supporting three rows of small cusps. *Tritylodon* in its molar teeth differs widely from the later multituberculates, except the Paleocene *Polymastodon* and its allies; and even these resemblances are very remote and apparently due to convergence. Possibly the "multituberculate" type of dentition was evolved more than once among the Mesozoic mammals, as we know that it was among the Tertiary mammals. The existence of this genus in the Lower Jurassic again emphasizes the extreme antiquity and independence of the multituberculate type of dentition, and strengthens the view that the Multituberculata have no near relationships with either the triconodont or the tituberculate orders.

The Mammals of the Purbeck and Morrison Beds (Upper Jurassic)

In the Purbeck Beds of England, of Upper Jurassic age, described especially by Owen (1871) and by Osborn (1888), is found a relatively numerous mammalian fauna consisting mostly of the lower jaws of minute mammals of diverse types. The Morrison formation of similar age in Wyoming, which has yielded the remains of many gigantic dinosaurs, also carries a closely similar mammalian micro-fauna.

ORDER MULTITUBERCULATA

Family Plagiaulacidæ

In the Purbeck Beds, the multituberculates are represented chiefly by the lower jaws of the highly specialized *Plagiaulax*, which had a single pair of enlarged, procumbent, piercing incisors, followed by a short diastema; premolars, three in number, compressed and bearing

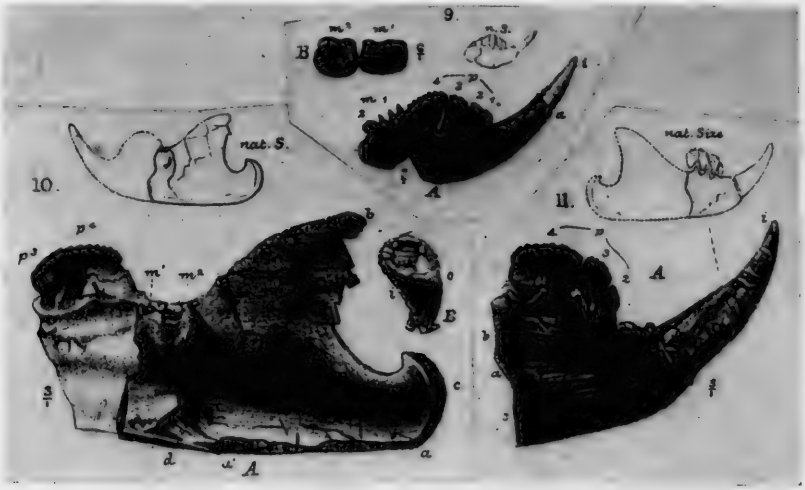


FIG. 21 LOWER JAWS AND TEETH OF *Plagiaulax*, A MULTITUBERCULATE FROM THE PURBECK BEDS (UPPER JURASSIC). AFTER OWEN

9—*Plagiaulax minor*, right ramus, lateral aspect; *n. s.*, natural size. *A*, the same; *B*, the two lower molars, ×6. 10.—*Plagiaulax becklesii*, portion and impression of right ramus; ×3. 11.—Counterpart impression and portion of the same ramus; natural size. *A*, the same; ×3/1.

many parallel, oblique ridges and grooves, the last premolar being very large and projecting far above the level of the molars; molars small, oval, with deep central fossa bordered by irregular cusps, the smaller and more numerous ones being on the buccal wall of the crown.

As shown by Gidley (1909, p. 612), the upper dentition of *Plagiaulax* is probably represented in the type of *Bolodon crassidens* Owen. One

pair of the upper incisors, possibly the second, is enlarged in opposition to the enlarged procumbent pair of lower incisors; the outermost incisors (possibly i_3) are small. There is a slight diastema followed by a straight row of cheek teeth, of which at least the first two have three rounded cusps with the apex on the *buccal* side, as in the Morrison genera *Ctenacodon* and *Allodon*. As shown by comparison with the Paleocene genus *Ptilodus*, these upper premolars may have served to hold the fruits or nuts in place and to assist in cracking them while the grooved lower premolars cut them.

The upper molars, as figured by Osborn, were elongate oval with two anteroposterior rows of three cusps, each separated by a median groove. Similarly in *Allodon*, from the Morrison formation, there were two rows of three cusps each separated by a long, straight central fossa. Here, again, the difference of the multituberculate type of dentition from those of the other contemporary orders is very great, and should discourage further attempts to derive it directly from the triconodont mammalian type rather than from some cynodont reptilian type, such as *Pachygeneleus* (see p. 118 above).

ORDER TRICONODONTA

Family Triconodontidæ

This group is now represented by numerous lower jaws of the genus *Triconodon* and the allied *Triacanthodon*. The jaw of *Triconodon mordax* is about 38 mm. in length, while that of *T. major* may have been about 55 mm. long. This was nearly twice as large as the jaw of the far more primitive *Amphilestes* of the Stonesfield Slate, and was almost gigantic in comparison with the diminutive jaw of *Stylodon pusillus* which was some 18 mm. in length. Thus, even in this micro-fauna, there was a wide variation in size; but even the largest animals were far smaller than their carnivorous analogues of later periods.

The lower molars of the Purbeck Triconodontidæ each bear three subequal, compressed, conical cusps arranged anteroposteriorly, and bordered by a stout internal cingulum. They have probably arisen through the increase in size of the anterior and posterior molar cusps of some such forms as *Amphilestes* and *Phascolotherium* of the Stones-

FIG. 22. UPPER AND LOWER JAWS OF TRICONODONTS FROM THE PURBECK BEDS (UPPER JURASSIC). AFTER OWEN

1.—*Triconodon mordax*, left mandibular ramus; natural size. *A*, the same; ×2. 11.—*Triconodon ferox*, left mandibular ramus, medial aspect; natural size. *A*, third molar; ×3. 17.—*Triconodon ferox*, portion of right maxilla, lingual aspect; natural size. *A*, the same; ×3. 2.—*Triconodon occisor*, right and left mandibular rami; natural size. 3.—*Triconodon major*, right mandibular ramus; natural size. 6.—*Triconodon minor*, right mandibular ramus; natural size. *A*, the same; ×3. 7.—*Triacanthodon serrula*, portion and impression of left mandibular ramus, natural size. *A*, the same; ×2. 8.—Counterpart impression, and portion, of the same ramus (7). *A*, the same; ×2.

field Slate fauna. As the anteroposterior diameter of each lower molar has now markedly increased, there has been a corresponding reduction in the total number of molars from five to three, or rarely four. A decrease in the number of molars, with a concomitant increase in the anteroposterior diameter of each, is also observable in comparing earlier with later members of several other phyla of mammals.

The upper molars are similar to the lower, but have the cingulum on the outer instead of on the inner side. The lower premolars, four in number, seem to have deciduous predecessors. In the lower jaw the apex of the fourth premolar is much higher than that of the first molar. The premolars have compressed protoconids and the crowns are simpler than those of the molars, but are beginning to develop the triconodont pattern. The fourth deciduous cheek tooth, as figured, is more molariform than its permanent successor, as is usually the case in all orders.

The dental formula of the adult is given as

$$I_{\frac{3}{3}}\ C_{\frac{1}{1}}\ P_{\frac{4}{4}}\ M_{\frac{3-4}{3-4}}$$

The lower jaw is stout, well curved below, with a prominent caniniform canine, a wide ascending ramus and fully inflected angle. The areas for the masseter and temporal muscles on the outer side, and for the pterygoid muscles on the inner side, are extensive. The condyle is in line with the lower border of the jaw, as it is also in the multituberculates. The typical triconodonts were thus evidently the aggressive carnivores of this micro-fauna, remote descendants perhaps of some of the smaller mammal-like reptiles, but already too specialized to be ancestral to the trituberculate marsupials and placentals.

In the Morrison formation of North America we find the true triconodonts represented by Marsh's genus, *Priacodon;* in which the internal cingula of the premolars and molars are strongly developed.

ORDER TRICONODONTA?

Family Spalacotheriidæ

Of uncertain relationships, but of considerable morphological interest, are the Purbeck genera, *Spalacotherium* Owen and *Phascolestes* Owen, represented by minute lower jaws with a slender horizontal ramus and sharp, pricking, molars of insectivorous type. The sharp proto-, para-, and metaconids constitute an equilateral triangle with the protoconid at the apex. Certain characteristics of the molars of *Spalacotherium tricuspidens*, as figured by Owen (1871, plate 1) and by Osborn (1888, plate 8), have given rise to the well-known "Cope-Osborn hypothesis" that the tritubercular lower molar arose through the "rotation" or circumduction of the anterior and posterior cusps toward the lingual side, so as to produce a triangular arrangement, the protoconid forming the apex on the outer or buccal side, and the main anterior and posterior cusps forming the para- and metaconids on the lingual side. The jaws of *Menacodon* Marsh and *Tinodon* Marsh, from the Morrison formation, have also given support to this suggestion because, both in the inner and outer views, their cheek teeth on the one hand recall the triconodont pattern, and on the other hand suggest that of *Spalacotherium*. Moreover, the angular region in a certain jaw referred to *Spalacotherium* appears to be strongly inflected as in the triconodont type.

It is indeed possible that, as suggested by Osborn (1888, p. 243), *Spalacotherium* and its American allies have been derived from a more primitive triconodont, such as *Phascolotherium* of the Stonesfield Slate, in which the anterior and posterior cusps were said to be slightly internal to the main cone, or protoconid.

The transition from the Spalacotheres to the true Trituberculata has not been satisfactorily established, although the lower jaws of "*Peramus*" offer some evidence in that direction, since they were referred originally to *Spalacotherium* but were subsequently shown by Osborn (1888.2, p. 295) to belong with *Peramus*. This genus has the asymmetrical trigonid of the trituberculates rather than the symmetrical trigonid of the spalacotheres.

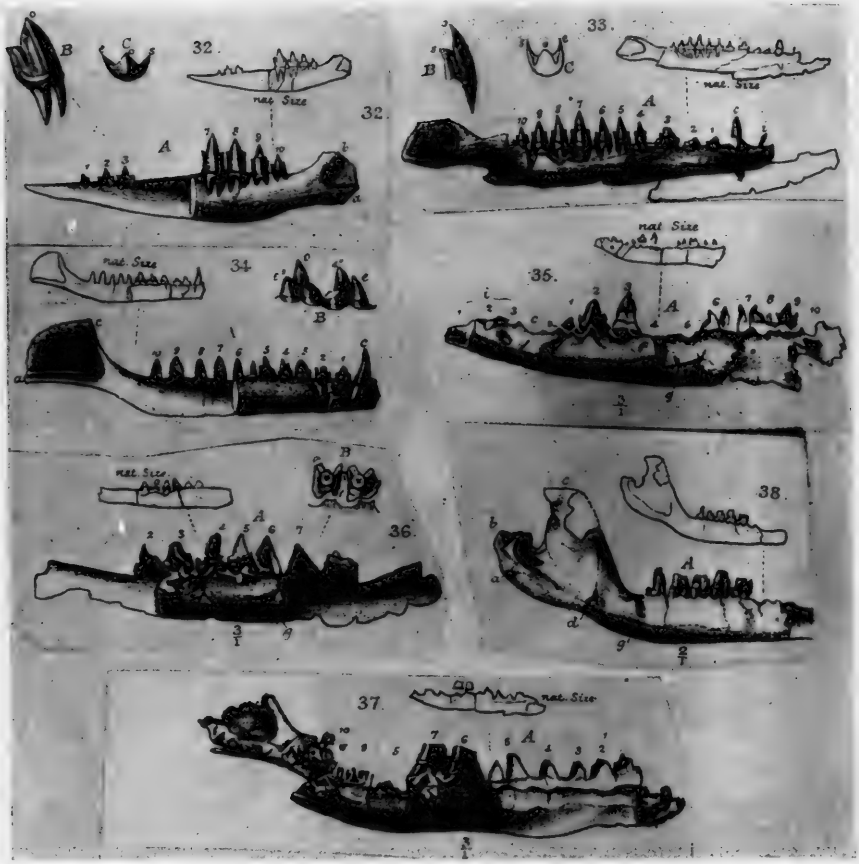


FIG. 23. LOWER JAWS OF *Spalacotherium tricuspidens*, FROM THE PURBECK FORMATION (UPPER JURASSIC). AFTER OWEN

32.—Portion of left ramus; natural size. *A*, The same; ×2. *B*, oblique view of a molar tooth; ×4. *C*, the same, upper view. 33.—Part of right ramus; natural size. *A*, the same; ×2. *B*, oblique view of a molar tooth. *C*, upper view of same. 34.—Part of left ramus; natural size. *A*, the same; ×2. *B*, inner view of two molars; ×4. 35.—Part of left ramus; natural size. *A*, the same; ×3. 36.—Part and impression of right ramus; natural size. *A*, the same; ×3. *B*, upper view of two fractured molars; ×3. 37.—Part and impression of the same ramus in the counterpart slab of matrix; natural size. *A*, the same; ×3. 38.—Left ramus; natural size. *A*, the same; ×3.

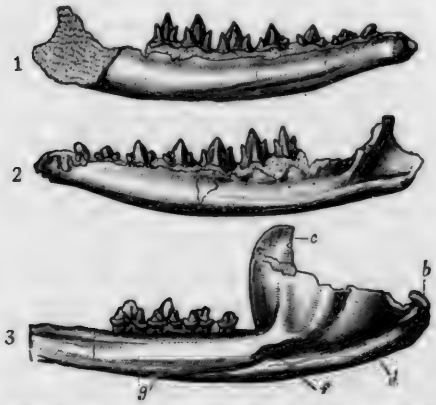


FIG. 24. LOWER JAWS OF *Menacodon rarus* AND *Tinodon bellus*, FROM THE MORRISON FORMATION (UPPER JURASSIC). AFTER MARSH

1.—*Menacodon*, left mandibular ramus, outer side. ×3. 2.—The same, inner side. ×3. 3.—*Tinodon bellus*, right mandibular ramus, inner side. ×3.

In the arrangement of the cusps of the lower molars, these genera are intermediate between the primitive triconodonts, such as *Amphilestes* and the spalacotheres, which have the three cusps arranged in a symmetrical triangle. Upon this fact was based the well known hypothesis of the origin of the tritubercular molar by the "rotation," or circumduction, of the para- and metacones toward the inner side of the lower molars.

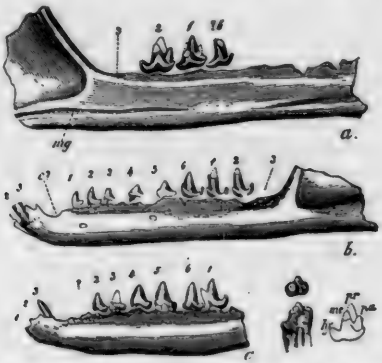


FIG. 25. LOWER JAWS OF *Peramus*, FROM THE PURBECK (UPPER JURASSIC). AFTER OSBORN. ALL MUCH ENLARGED

a.—*Peramus* (*Spalacotherium*) *minus*, left ramus, inner side. b.—*P.* (*Leptocladus*) *dubius*, left ramus, outer side. c.—*P. tenuirostris*, left ramus, outer side.

Also second lower molar of *Amphitherium prevostii*, internal view, and second molar of *Peramus minus*.

The lower molars have the asymmetrical trigonid, as in most other trituberculates and unlike the symmetrical trigonid of the spalacotheres. The presence of six premolars and three molars is peculiar.

The most important objection to the "cusp rotation" hypothesis is that, in the far older Jurassic fauna of the Stonesfield Slate, the primitive triconodont and tritubercular patterns were already widely different and were possessed by animals belonging to different orders; the primitive triconodonts, *Amphilestes* and *Phascolotherium*, apparently belonging among the Marsupialia, and having the angle of the jaw sharply inflected, while the primitive trituberculate, *Amphitherium*, represented the order Trituberculate, in which the angular process was conspicuous and not inflected. Hence, if some of the so-called trituberculates of the Purbeck fauna, such as *Spalacotherium* and its allies, were derived from the primitive triconodonts, this does not establish their status as true Trituberculata, for they may have been only Pseudo-trituberculata. Professor Osborn in 1888 (p. 245) and again in 1907 (p. 8) suggested that the trituberculate lower-molar pattern may have been derived more than once and in more than one manner, viz.: first, as an upgrowth of the internal cingulum in the true Trituberculata; secondly, as a result of the inward displacement of the anterior and posterior cusps in the Pseudotrituberculata.

Finally, there is no evidence that these pseudo-trituberculates of the Upper Jurassic were ancestral to any of the better known mammals of the later ages.

ORDER TRITUBERCULATA

Family Amphitheriidæ

In the typical Purbeck trituberculates, as represented by *Amblotherium* and *Achyrodon*, the asymmetry of the trigonid is pronounced. The metaconid is now opposite the posterior slope of the protoconid while the paraconid, instead of pointing solely upward, is often directed more forward so as to make a pronounced fork with the protoconid. The incipient talonid, which is lacking in *Spalacotherium*, also now bears a rather prominent low projection, the homologue of the entoconid of later mammals. Thus in these genera the lower teeth represent an advance upon the more primitive type seen in *Amphitherium* of an older horizon. Their lower jaw agrees in essentials with that of *Amphitherium*, since it has a well-defined angular process

and is therefore of the primitive placental type. In *Amblotherium mustelula* the jaw is stouter, the ascending ramus is broader, its coronoid border is more vertical, and its condyle is at a higher level above the alveolar border, recalling the conditions in *Amphitherium;* while in *Amblotherium soricinum*, the ascending ramus is narrower, its coronoid border more sloping, and the condyle set at a lower

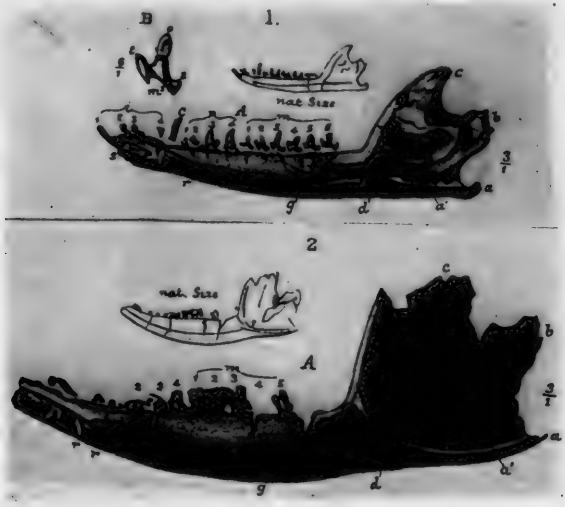


FIG. 26. LOWER JAWS OF *Amblotherium*, FROM THE PURBECK FORMATION, UPPER JURASSIC. AFTER OWEN

1.—Right ramus of *Amblotherium soricinum;* natural size. *A*, the same; ×3. *B*, third molar; ×6. This view shows the paraconid (c), the high protoconid (o), the metaconid, and the low small talonid (s). 2.—Right ramus of *Amblotherium mustelula;* natural size. *A*, the same; ×3.

This jaw, as figured, differs widely from that of *Amblotherium soricinum* and, perhaps, represents a more aggressive carnivorous member of the Amphitheriidæ.

level. These differences are perhaps correlated with equal differences in food habits, *A. mustelula* possibly being carnivorous and *A. soricinum* more insectivorous. The dental formula of the latter, $I_{\frac{1}{1}}\, C_{\frac{1}{1}}\, P_{\frac{4}{4}}\, M_{\frac{6}{6}}$ is similar to that of *Amphitherium*, $I_{\frac{4}{4}}\, C_{\frac{1}{1}}\, P_{\frac{5}{5}}\, M_{\frac{6}{6}}$. The incisors are gently procumbent and slightly spatulate; the canine, erect. The premolars increase in size from the very minute P_1 to

the large erect P_4 which has a recurved apex of piercing and pricking type. The molars increase in size posteriorly, the first being quite small. Somewhat similar but less pronounced characters may be observed in the older *Amphitherium* and in many of the contemporary trituberculates of the Purbeck beds.

For the purposes of this discussion the genera *Amphitherium*, *Achyrodon*, *Peraspalax* and perhaps *Peralestes* described below, may be referred to the family Amphitheriidæ of Owen, which, together with the Stylodontidæ, constitute the order Trituberculata of Osborn, the Pantotheria of Marsh.

In America the Amphitheriidæ appear to be represented in the Morrison formation by the genus *Paurodon* of Marsh. In this

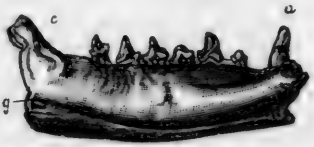


FIG. 27. PART OF LEFT MANDIBULAR RAMUS OF *Paurodon valens*, FROM THE MORRISON FORMATION (UPPER JURASSIC) OF WYOMING. ×3. FROM OSBORN, AFTER MARSH.

In this genus, as in certain other Jurassic trituberculates, (e.g., *Achyrodon*), the inner cusps (para-, meta-, and entoconids) look as if they might have grown up from the internal cingulum. The number of post-canine teeth, six, is the lowest in any Jurassic trituberculate. The jaw is remarkably short and deep.

lower jaw, as figured, the molars approach those of *Peraspalax* Owen in the asymmetrical arrangement of the trigonid, in which the metaconid is opposite the posterior slope of the protoconid, and the basal spur, or talonid, is well defined. If the high, erect tooth in the anterior part of the mandible is really a canine, then *Paurodon*, as its name implies, has a reduced number of post-canine teeth, the premolars and molars being only six in number. If this is the fact, *Paurodon* would perhaps have to be made the type of a distinct family, but before this is done it should be ascertained whether the large erect tooth is not the posterior premolar (p_4). In this genus, as well as in the Amphiteriidæ of Europe, the para- and metaconid and the internal tip of the talonid or entoconid suggest derivation from the internal cingulum; but, as before, no decisive evidence is available.

ORDER TRITUBERCULATA

Family Stylodontidæ

The family Stylodontidæ is represented, in Europe, in the Purbeck Beds, by the genus *Stylodon* and, in America, by the genera *Stylacodon*, *Asthenodon* and, perhaps, by *Dryolestes* and *Laodon*. In the first three genera the molar teeth, as seen from the outside, form narrow,

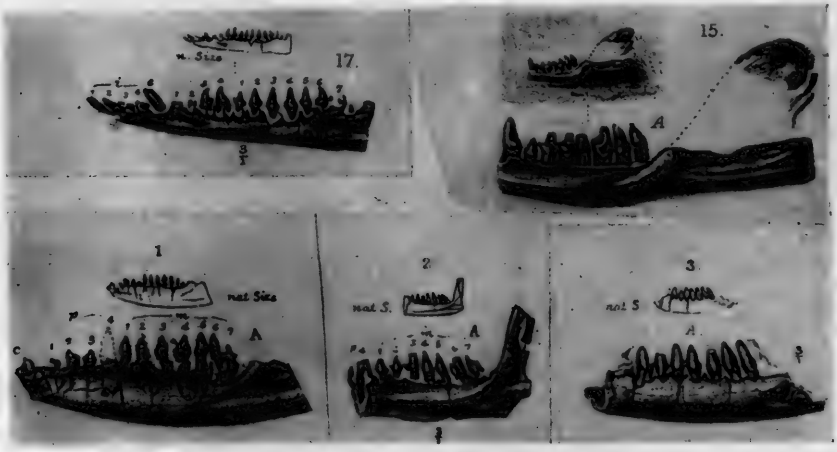


FIG. 28. LOWER JAWS OF *Stylodon*, FROM THE PURBECK FORMATION. AFTER OWEN

17.—*Stylodon pusillus*, fore part of left ramus; natural size. *A*, the same; ×3. 15—*Stylodon pusillus*, hind part of left ramus; natural size. *A*, the same; ×3. 1.—*Stylodon robustus*, left ramus; natural size. *A*, the same; ×3. 2.—*Stylodon pusillus*, left ramus; natural size. *A*, the same; ×3; showing the forward inclination of molars 5, 6, 7. 3.—*Stylodon pusillus*, left ramus; natural size. *A*, the same; ×3.

This genus represents an advanced specialization for insectivorous or vermivorous habits.

high, sharply-pointed columns (*Stylodon* = column tooth) which, by analogy with certain living insectivores, were adapted for piercing the shells of insects and, perhaps, for holding and piercing the writhing bodies of worms. These molars contrast with those of the Amphitheriidæ, first, in the extreme anteroposterior narrowness of their tips; secondly, in the presence of pronounced interspaces between the molars which are not interrupted by any basal expansion, or talonid,

but continue down between the roots to the alveolar border; thirdly, in the extreme anteroposterior shortness of the molars, which brings the anterior and posterior roots so close together that, from the outside at least, they appear to be coalesced. From the inner side, as figured, they can be barely, if at all, differentiated; while in the Amphitheriidæ, the two main roots of each molar are widely separated, especially on the inner aspect of the jaw. Fourthly, the horizontal ramus in most cases is very slender, although *Stylodon robustus* forms an exception to this rule. The dental formula $I_{\frac{3}{3}}$ $C_{\frac{1}{1}}$ $P_{\frac{3}{3}}$ $M_{\frac{7-8?}{7-8?}}$ differs from that of the Amphiteriidæ only in the slightly greater number of the molars, but it must be remarked that certain genera are referred to the Amphitheriidæ (*Achyrodon*, *Peraspalax*) in which there are also seven or eight molars. Significant agreement is found not only in the dental formula but also in the presence of a distinct angular process on the mandible, of a pedunculate condyle, and, especially, in the characters of the premolars, which retain the primitive two roots and increase rapidly in size from p_1 to p_4, so that the premolars of *Stylodon* and *Dryolestes* are similar to those of *Amblotherium*, *Peralestes* and *Achyrodon*. The lower molars of *Laodon* and *Dryolestes*, as figured, are essentially similar to those of *Peraspalax*, *Peralestes* and *Achyrodon* of the Amphitheriidæ. Therefore, it seems safe to infer, from the construction of the lower jaw and lower molars, that the Stylodontidæ represent a structural advance upon the Amphitheriidæ, leading towards extreme insectivorous adaptations.

Possibly some of the less specialized members of the Stylodontidæ might have given rise to the zalambdodont Insectivora of the Paleocene and later epochs, but, in the absence of real connecting links, such an inference could be at most provisional; because this high, styloid, sharply-pointed type of lower molars has apparently been evolved independently in the marsupials and placentals. The Stylodontidæ differ from the later insectivorous mammals in having a large number of molars, all of relatively small size; but this is possibly a primitive character and the reduction of the molars in the later placentals is very probably secondary. The Stylodontidæ, therefore, tell us nothing decisive about the origin of the tritubercular type of lower molar. They merely exhibit an early specialization of that type, probably derived from the more primitive conditions seen in the Amphitheriidæ.

UPPER MOLARS OF PURBECK TRITUBERCULATA

Up to this point I have purposely omitted a discussion of the upper molars because the classification and relationships of these families must first be worked out on the lower molars, and because of the uncertain systematic position of one of the upper molar types now to be described.

Kurtodon

In the Purbeck Beds there are only two types of upper molars known which may be assigned to the order Trituberculata. One of them, referred to *Stylodon* by Owen, was made the type of a new

FIG. 29. LEFT PREMAXILLA AND MAXILLA OF *Stylodon pusillus* FROM THE PURBECK FORMATION (UPPER JURASSIC). AFTER OWEN

14.—Natural size. *A*, the same; ×3. *B*, crown view of sixth and seventh molars; ×3.

In this genus, as in all other trituberculates, the main tips of the molars appear to be serially homologous with those of the premolars.

genus, *Kurtodon*, and of a new family, Kurtodontidæ, by Osborn, who, however, afterward (1888.2) recognized that *Kurtodon* belongs in the Stylodontidæ. The material consists only of a minute alveolar process and premaxilla, 13 mm. long, exposed, it is said, on the lingual side. The molars are very wide transversely and short anteroposteriorly. Thus, they consist of a narrow V-shaped crown with the high apex on the lingual side. The surface of the crown is apparently worn off, but bears a narrow low ridge running transversely from the internal apex. The dental formula includes one canine, four premolars and seven molars, and is apparently the same as in

Stylodon pusillus and in the American genus, *Dryolestes*, mentioned above. The fourth premolar is much larger than the first molar, as is usually the case in Mesozoic trituberculates. As figured, it suggests in every way the corresponding lower tooth of *S. pusillus*, as also does the third premolar. The canine is large, directed downward and somewhat backward.

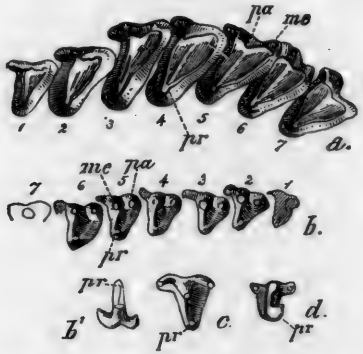


FIG. 30. UPPER AND LOWER MOLARS OF CERTAIN TRITUBERCULATES FROM THE PURBECK FORMATION (UPPER JURASSIC). AFTER OSBORN. ALL MUCH ENLARGED

a.—*Stylodon* (*Kurtodon*) *pusillus*, left upper molars, crown view. b.—Right lower molars of *Amblotherium soricinum*, crown view. b^1, a left lower molar of *Amblotherium* (*Peraspalax*) *talpoides*, outer side, showing the protoconid, paraconid, and entoconid. c.—A left lower molar of the same species, viewed obliquely from above, showing the asymmetrical trigonid, with oblique anterior, and directly transverse, crests; and the incipient talonid bearing the low entoconid. d.—A left lower molar of *Achyrodon nanus;* crown view showing the worn transverse crest connecting the protoconid with the metaconid.

Dryolestes

From the Morrison formation of America there are two sets of upper teeth of *Dryolestes* figured by Osborn which resemble Osborn's later figure of the *Kurtodon* type (1907, p. 26) in many important characters; and, as they are probably associated with lower molars referred to the Stylodontidæ, they tend strongly to support Owen's original conclusion that the *Kurtodon* upper molars belong with, or near, the *Stylodon* lower molars.

The *Dryolestes* upper molars are separated on the inner side by triangular spaces for the reception of the trigonids of the lower molars. This interlocking of the lower molars with the spaces between the upper molars is a fundamental relation in all primitive tritubercular dentitions. Attention was so long directed solely to the question of the homology and origin of the several cusps of the primitive trigon, that the importance of the interlocking relation, the trigonids fitting into the spaces between the upper molars, was not at first fully ap-

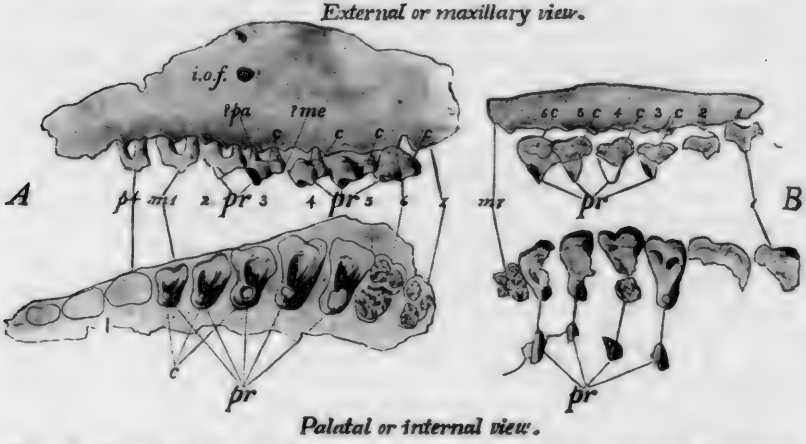


FIG. 31. UPPER MOLARS OF *Dryolestes* sp., A TRITUBERCULATE FROM THE MORRISON FORMATION (UPPER JURASSIC). GREATLY ENLARGED. AFTER OSBORN

From specimens in the Yale University Museum.

A.—Left maxilla. B.—Right maxilla. The cusps marked "pr" (protocone) are probably homologous with the tips of the premolars, and with the para- and metacones of later mammals.

preciated. In *Dryolestes*, as in other primitive tritubercular dentitions, no cusps of the triangular upper-molar crown could have articulated in vertical opposition with any cusps of the lower molars. The sharp sides of the upper molars sheared past the sides of the trigonids and therefore served as cutting blades. The protoconids of the lower molars certainly did not articulate with any upper cusp, but fitted into the buccal part of the triangular spaces between the upper molars. So, too, the high, pointed internal apex of the upper molars fitted chiefly into the spaces between the trigonids of the lower molars.

The basin-like surface of the upper molar crowns, although worn in both *Dryolestes* and *Kurtodon*, was not so worn by articulation with any part of the lower molar crowns, but by attrition with food. It is indeed a fundamental principle deduced from the observed occlusion of upper and lower teeth of many later mammals, that, in primitive tritubercular dentitions, the upper and lower triangles (trigon and trigonid) do not articulate vertically with, but shear past, each other, and that their summits are worn by attrition with food and not by articulation.

In the lower molars of *Dryolestes* there is a small talonid spur on the lingual side, the outer side of which sheared past the inner side of the apex of the upper molars. The upward movement of these talonid spurs was apparently checked by an incipient cingulum-like basal spur on the inner side of the upper molars, as figured by Osborn.

FIG. 32. PROBABLE OCCLUSAL RELATIONS OF UPPER AND LOWER MOLARS OF *Dryolestes*

The homology of the internal apex of the upper molars of *Dryolestes* has been disputed. Osborn (1904, 1907, p. 217) claimed that it was homologous both with the "apex of the original reptilian cone" and with the "protocone" of later tritubercular dentitions. Gidley (1906), held that the cusp in question represented a secondary extension from the inner sides of the upper molars analogous with a similar internal extension of the premolars of later mammals. For the reasons stated below (p. 147) it now appears that the internal apex of the *Dryolestes* molars is homologous with the "apex of the original reptilian cone" but not with the "protocone" of later mammals.

Peralestes

A second type of trituberculate upper molars from the Purbeck Beds is afforded by the alveolar process described by Owen as *Peralestes longirostris*. The upper molars of this genus differ widely from

those of the *Kurtodon* and *Dryolestes* type. Instead of being very narrow, transversely extended and anteroposteriorly shortened, each upper molar in crown view shows a wide asymmetrical triangle with very high internal tip and low anteroexternal cusp connected with a

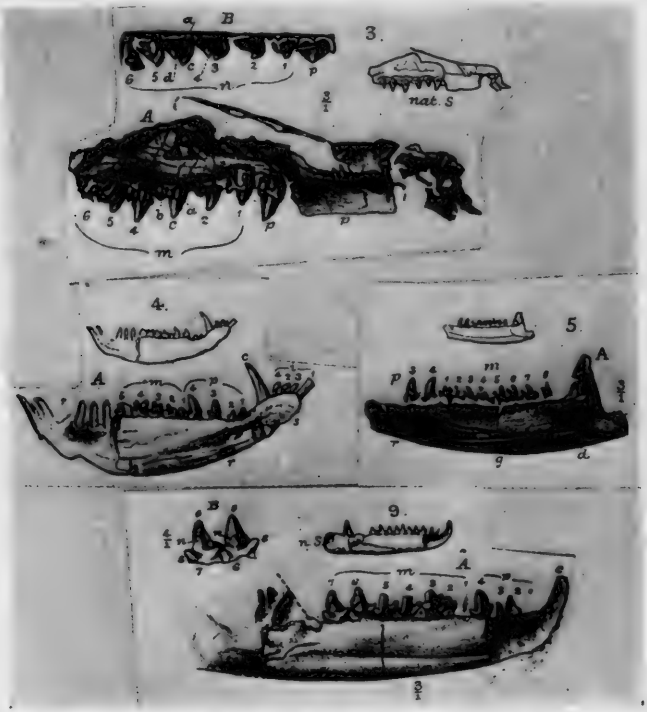


FIG. 33. UPPER AND LOWER MOLARS OF *Peralestes* AND OTHER PURBECK TRITUBERCULATES. AFTER OWEN

3.—Right maxilla of *Peralestes longirostris;* natural size. *A*, the same; ×3 *B*, crown view of upper molars. 4.—Left mandibular ramus, referred by Owen to *Peralestes longirostris;* natural size. A, the same; ×3. In this drawing, only the internal cusps of the molars (para-, meta-, and entoconids) are shown the protoconids being probably hidden in the matrix. 5.—Left mandibular of *Achyrodon nanus;* natural size. A, the same; × 3. 9.—Left mandibular ramus of *Peraspalax talpoides;* natural size. A, the same; ×3. B, sixth and seventh lower molars, lingual side; ×4. *e*, paraconid; *n*, metaconid; *c*, protoconid; *s*, entoconid (incipient talonid).

The very asymmetrical trigon and high apices of the upper molars of *Peralestes* suggest that somewhat similar conditions would be found in the lower molars, as in the present specimens.

pronounced external cingulum, and a third prominent cusp on the posteroexternal slope of the high internal cusps. As we pass forward, the high internal cusps of the molars are certainly homologous with the still higher apex of the fourth premolar, the molars and the premolars being supported by two widely separated roots arranged anteroposteriorly, as are the roots of the lower cheek teeth in the Amphitheriidæ.

Owen (plate II, fig. 4) associated these upper teeth of *Peralestes* with a certain lower jaw which Osborn referred to *Phascolestes;* but both Owen and Osborn agree in associating the upper molars of *Peralestes* with lower molars which the present writer would refer to the Amphitheriidæ, in its wider sense, in contrast with the group here

FIG. 34. UPPER MOLARS OF *Peralestes longirostris*. ×5. AFTER OSBORN

In the outer view, the apices of the molars are serially homologous with those of the premolars. The sharp blade-like edges of the molars probably sheared past equally sharp crests running from the protoconid to the metaconid in the lower molars. The lower figures show two of the molars (possibly the second and the fourth) in crown view. In general, these teeth are very different from those of *Dryolestes*.

called Stylodontidæ, which are distinguished by their very narrow molars. In his book on the "Evolution of mammalian molar teeth," however, Professor Osborn referred *Peralestes* provisionally to the Spalacotheriidæ along with the lower teeth called *Phascolestes*. After studying the various figures by Osborn and Owen, I believe that Osborn's earlier opinion was more nearly right, and that *Peralestes* with its asymmetrical, wide, triangular upper crowns represents the upper dentition of some of the Amphitheriidæ, especially *Achyrodon;* or even that Owen was right in referring to *Peralestes* the lower jaw shown in his Plate II, fig. 4.

Peralestes, therefore, appears to be a member of the Amphitheriidæ, and it may give us some idea of the general appearance of the upper

molars of the older *Amphitherium*, but was probably somewhat more specialized. It strongly supports the view that, in the Mesozoic Trituberculata, the tips of the upper protocones were serially homologous with the tip of the posterior premolar. This conclusion, in turn, is in line with the conclusions of the "premolar analogy" theory based on studies of later mammals. Assuming for the moment the correctness of this view, the tips of the upper molars of *Peralestes*, as well as those of *Dryolestes*, are to be regarded as homologous with the paracones and not with the protocones of the molars of later mammals. In 1916 I pointed out the resemblance between the upper teeth of *Peralestes* and the deciduous teeth of the polyprotodont marsupials, and suggested that the high internal cusp is homologous, not with the protocones, but with either the para- or metacones of marsupials.

ORDER TRITUBERCULATA

Family Diplocynodontidæ

Of the Upper Jurassic mammals there remains to be considered a peculiar and aberrant family, the Diplocynodontidæ or Dicrocynodontidæ, from the Morrison formation of Wyoming. The upper molars, as figured by Gidley, have a high, compressed, external cusp and a large, highly peculiar, internal cusp, connected with the principal external cusp by a low transverse ridge. The inner cusp is greatly expanded anteroposteriorly at the base, both its anterior and its posterior buccal surfaces bearing deep fossæ for the reception of lingual cusps of the lower molar trigonids. These strange upper molars, which might possibly be derived from a *Diademodon*-like pattern, are very doubtfully referred to the same family with lower jaws, of the type called *Docodon* by Marsh. Gidley pointed out the apparent homologies of the several parts of the upper molars of *Diplocynodon* with those of *Dryolestes;* on the other hand the supposed lower dentition of the Diplocynodonts, distinguished by the large size and oblique form of the trigonids, indicates ordinal relationships with *Peralestes* among the Amphitheriidæ. After many attempts I have failed to find a satisfactory solution of the problem of the articulating relations of the upper and lower molars of this

family and until this is achieved the homologies of the several parts, and the supposed association of upper and lower molars, remain in doubt.

To summarize, the upper as well as the lower molars of these upper Jurassic trituberculates already exhibit considerable diversity in form. Some, e.g., *Kurtodon*, *Dryolestes*, suggest the narrow tritubercular type of *Chrysochloris* among living marsupials, but, in view of the plasticity of the mammalian dentition, it would not be safe to regard

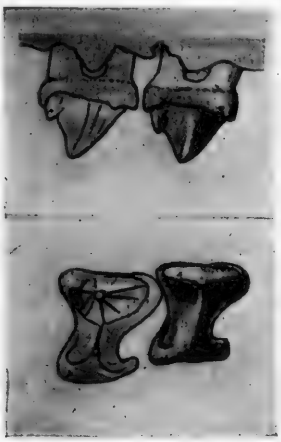


FIG. 35. TWO UPPER MOLARS OF *Dicrocynodon* SP., MORRISON FORMATION (UPPER JURASSIC). ×6. AFTER GIDLEY

These strange upper molars probably represent very aberrant relatives of the Amphitheriidæ.

them as directly ancestral to that genus, which appears to be connected rather with the other polyprotodont marsupials. The second type of upper molars, those of *Peralestes*, in some respects foreshadows the upper-molar patterns of the opossums and other polyprotodonts, but here again there are no intermediate links tending to connect the two. The third type, *Diplocynodon*, may well represent a peculiar line of specialization, the members of which became wholly extinct.

Summary and Defense of the Primitive Characters of the Lower Jurassic Amphitherium

As a whole, both the upper and lower molars afford very strong evidence for the view that, in the Jurassic trituberculates, the main tips of the molars were homologous with those of the premolars. The Purbeck genera may all represent specializations from the primitive *Amphitherium*-like type, but by themselves they tell us little about the origin of the tritubercular type, unless one is willing to admit without evidence the hypothesis that the primitive Lower Jurassic Amphitheriidæ are descendants of unknown earlier Spalacotheriidæ, the lower-molar pattern of which was by hypothesis derived through the circumduction of the anterior and posterior cusps of a primitive *Phascolotherium*-like triconodont.

We have now to consider in conclusion a possible objection to the view that the Lower Jurassic trituberculates are really primitive and structurally ancestral to later trituberculate mammals. It is possible to argue that the known Jurassic faunæ, coming as they do from two or three extremely limited localities, represent only a fraction of the mammalian life of that epoch; that they belong only in the swamp or lowland fauna associated with the giant reptiles; and that such faunæ usually consist of the more degenerate or aberrant relatives of the more primitive faunæ of the uplands, which in this case have been entirely wiped out. From this point of view many of the characters here regarded as primitive, such as the small size of the talonid and the high number of post-canine teeth, would be under the suspicion of being secondary, not primitive. Against such an argument I would advance the following considerations:

(1) The considerable number of genera represented in the Purbeck trituberculates is favorable to the probability that some of them will be more primitive in certain characters than others, that is, will preserve more of the characters of their hypothetical ancestors of the uplands.

(2) If it be admitted that the Stylodontidæ, with high, narrow molars, are relatively specialized, it seems that *Amblotherium soricinum* is a more primitive member of the Purbeck trituberculates, which has apparently inherited many characters from a much older

form like *Amphitherium* of the Stonesfield Slate (Lower Jurassic), such as the following: lower incisors four, semiprocumbent; canine erect, caniniform, with more or less division of the fang; lower premolars four (but probably five in *Amphitherium*), with simple, conical crowns, incipient talonid and two roots; the last premolar high and projecting above the level of the molars; lower molars six, tritubercular, with incipient talonid; lower jaw with a wide coronoid process, ascending at a low angle; condyle lower than in typical later mammals, angular process of mandible hook-like, not inflected; Meckelian groove of jaw pronounced; diet prevailingly insectivorous; size much smaller than the average size of later mammals.

(3) The conclusion that at least most of the foregoing are primitive characters rests upon the direct evidence cited in the preceding pages and in the writer's opinion outweighs the negative objection noted. Although members of swamp faunas are specialized in certain features, this is often not inconsistent with their retaining many primitive characters, as in the case of certain stegocephs and primitive reptiles.

(4) Of the characters listed above as primitive for *Amblotherium* and *Amphitherium*, perhaps the only one requiring special defense is the high number of post-canine cheek teeth. In all really primitive marsupials and placentals of later ages this never exceeds seven, while in *Amphitherium* it is eleven. It has been shown above that in the very primitive triconodont *Amphilestes*, of the Stonesfield Slate, there are ten post-canine teeth, while in the specialized *Triconodon* of the Purbeck there are but seven, or at most eight. The reduction in the number of molars from five to three is at least accompanied, if not caused, by a marked increase in the anteroposterior diameter of the individual teeth. So, too, in the primitive marsupials and placentals of later ages, in which the number of lower molars is reduced to three, each of these molars is elongate anteroposteriorly, due partly to the great expansion of the talonids, so that three wide molars occupy as much space in the jaw as did the six narrow molars of *Amphitherium*. In the opposite direction, a marked increase in the length of the jaw affords opportunity for a secondarily increased number of small molars, as in *Myrmecobius* and perhaps also in the stylodonts, where the molars are sometimes as many as nine in number.

The writer's general conclusion is that although the Lower Jurassic *Amphitherium* may well be ancestral to the specialized stylodonts of the Upper Jurassic, it is at the same time an exceedingly primitive mammal, which may be assumed provisionally as structurally ancestral to the placentals and perhaps also to the marsupials of later ages. Thus, it represents a remote stage in the evolution of the human dentition.

V. THE LATE MESOZOIC MAMMALS (UPPER CRETACEOUS)

Between the Upper Jurassic of the Purbeck-Morrison fauna and the next known mammalian fauna of the "Laramie," or Upper Cretaceous, of North America, there is a vast hiatus in the record representing millions of years of slow evolution, during which time the highly diversified reptilian orders dominate the geological record to the exclusion of the mammals.

The scarce mammals of the Upper Cretaceous, the contemporaries of the last of the dinosaurs, afford two radically different general types of dentition, which have been described by Cope, Marsh, Osborn, Gidley and Matthew: the first represents the later stages of the Multituberculata; the second, several modifications of the tritubercular type of molars.

ORDER MULTITUBERCULATA

Family Polymastodontidæ

The multituberculates, represented by *Meniscoessus* (described by Cope and by Osborn), enter a side path of evolution in which the upper molars tend to acquire three rows of cusps. The compressed and grooved lower premolar is not so large or elongate anteroposteriorly as it is in the typical Plagiaulacidæ, a stage foreshadowing the great reduction of this tooth in the polymastodonts of the succeeding Paleocene.

ORDER MARSUPIALIA, *SUBORDER* POLYPROTODONTIA

Family Cimolestidæ

The tritubercular molars, according to Matthew (1916), belong to small polyprotodont marsupials, some of which (*Eodelphis browni*) are closely related, or ancestral to, the modern opossums. In the lower jaw of this animal, the dental formula, as determined by Matthew (3, 1, 3, 4), differs from that of *Didelphis* only in the presence of three rather than four incisors. It differs from that of the Jurassic trituberculates in the reduction in number both of the premolars and of the molars. But, while the teeth are fewer in number

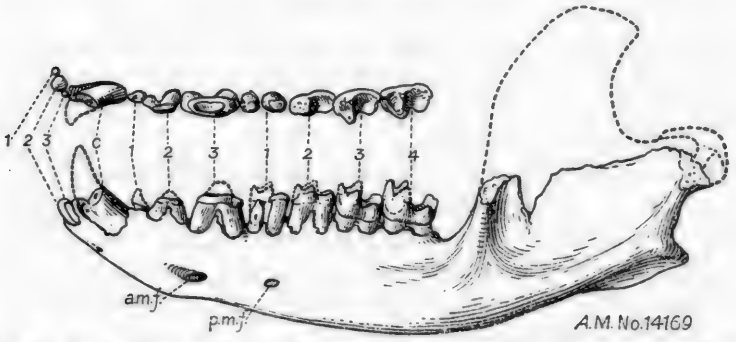


FIG. 36. LOWER JAW OF *Eodelphis browni*, A PRIMITIVE OPOSSUM FROM THE BELLY RIVER FORMATION (UPPER CRETACEOUS) OF ALBERTA. ×3/2. AFTER MATTHEW

they are individually much larger in proportion to the length of the jaw, which is also heavier than that of the trituberculates. The animal itself is very much larger, the jaw being about 62 mm. long, while that of *Amphitherium* is about 25 mm. long.

A progressive increase in size is observable in many phyla of mammals; and, in nearly all cases in which the palæontological history is known, the earliest species of the phyla average smaller in size than the later stages. Thus this extremely primitive Upper Cretaceous marsupial *Eodelphis* is intermediate in size between the primitive Jurassic trituberculates and the largest modern polyprotodont marsupials.

Eodelphis agrees with the more primitive existing polyprotodonts in having three premolars and four molars, in contrast with the four premolars and three molars of primitive placentals. Opinions differ so widely on the subject of the homologies of the premolars and molars in marsupials and placentals that it would require too long a digression to discuss the subject. It is not definitely known whether the last premolar of marsupials is homologous, as it appears to be, with the last premolar of Jurassic trituberculates and with the last, or fourth, premolar of placentals. The second and third premolars of *Eodelphis*, and all the molars, are supported by two main anterior and posterior roots, which appear to be homologous with those of the Jurassic trituberculates. The premolars have simple compressed crowns with a single tip, like those of the modern opossums. In the molars, the talonids are much better developed than those of the Amphitheriidæ, occupying the posterior moiety of the tooth, being extended transversely and bearing a hypoconid or posteroexternal lower cusp in addition to the primitive entoconid. In correlation with the better development of the talonids we find that the upper molars of these Upper Cretaceous marsupials (represented perhaps by ?*Pediomys* Marsh) have widened internal cusps or protocones, which apparently now fit into the basins or fossæ of the talonids of the lower molars. This relation, which first becomes clear in these Upper Cretaceous mammals, is very characteristic of all primitive later mammals, and was apparently attained through the upgrowth of the hypoconids on the outer side of the talonid spurs overlapping the internal tip of the upper "protocones." There seems no reason to doubt that, in the lower teeth, the tips of the premolars are homologous with the protoconids of the molars; and, presumably, in the upper teeth, the tips of the premolars, if known, would be homologous with the para- and metacones of the molars, as they are apparently in living polyprotodonts.

The upper molars of *Pediomys*, another Upper Cretaceous marsupial figured by Gidley (1906), and Osborn (1907), now have two well separated cusps, corresponding to the para- and metacones of later mammals. The separation of these two cusps is correlated with the transverse widening of the talonid, and with the upgrowth of a hypoconid which articulates on the surface of the crown between

the lingual slopes of the para- and metacones. There are now, also, two small intermediate V-shaped cusps, the proto- and metaconules, located respectively on the anterior and posterior slopes of the protocone. The appearance of these cusps was probably correlated both with the transverse widening of the talonid and with the shearing action of the trigonid. The protoconule fits into the reëntrant valley between the posteroexternal blade of the protoconid and the crista obliqua of the talonid. Similarly, the metaconule occludes, and has developed in, the space between the posteroexternal wall of

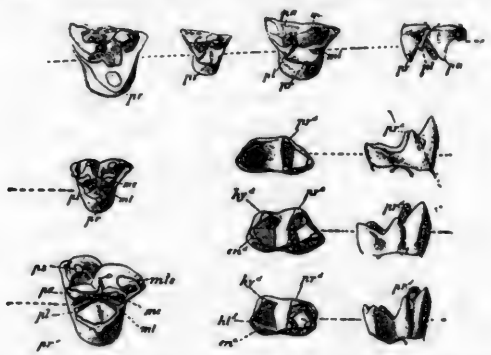


FIG. 37. UPPER AND LOWER MOLARS OF UPPER CRETACEOUS MARSUPIALS. ×2. AFTER OSBORN

Upper row: upper molars, *Protolambda* (cf. *Pediomys*). Middle and lower rows: upper and lower molars of *Didelphops* (?*Thlæodon*).

In some of these Upper Cretaceous marsupials, the upper molar cusps that developed from the external cingulum attained very large size. The lower molars are of the tuberculo-sectorial type, with high trigonids and well developed talonids, which, however, are not as large as those of typical placental mammals.

the hypoconid and the anteroexternal wall of the paraconid of the next succeeding lower molar. The metaconule, according to Gidley, was already developed in the Upper Jurassic *Dryolestes*, where its posterior side must have been appressed to the anteroexternal side of the trigonid.

The upper molars of *Pediomys* have a large internal cusp or "protocone," which is pretty surely homologous with the "protocone" of modern opossums. This, in turn, has probably arisen by a lingual extension of the base of the crown, while the original apex of the

crown, homologous with the tips of the premolars, has apparently remained in the middle of the crown and probably homologous with the para-metacone. Therefore, the direct comparison of the upper molars of *Pediomys* with those of the Jurassic trituberculates, *Dryolestes* and *Peralestes*, is probably misleading, since it would lead one at first sight to homologize the internal tip of its crown, which is

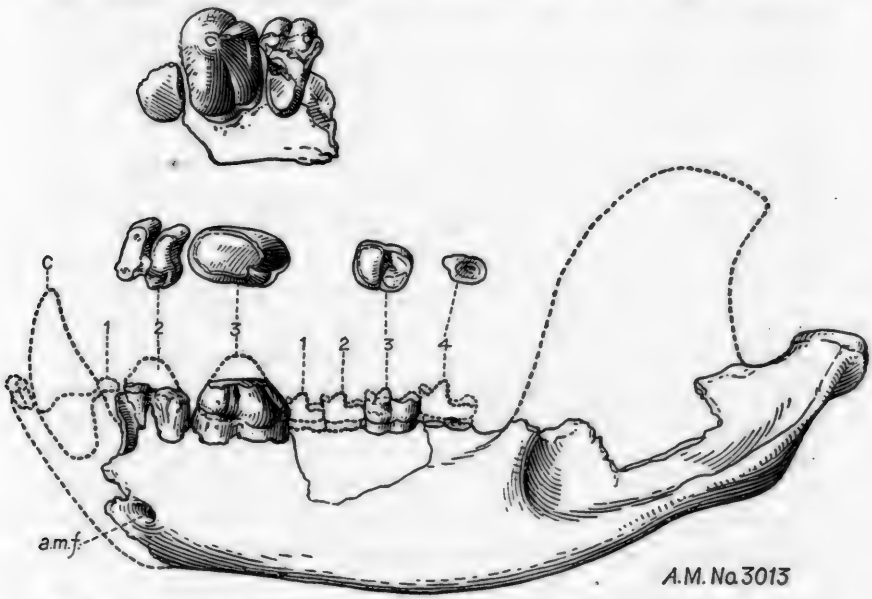


FIG. 38. *Thlæodon padanicus*, AN UPPER CRETACEOUS MARSUPIAL. ×3/2. AFTER MATTHEW

Fragment of left maxilla, with enlarged posterior premolar and first molar; crown view of lower teeth, and left mandibular ramus.

In this genus, the posterior premolars are enlarged, with swollen tips; the upper molars have swollen para- and metastyles; the lower molars are of the tuberculo-sectorial type.

probably a secondary ingrowth, with the primary apex of the molars of *Dryolestes* and *Peralestes*.

The upper molars of *Pediomys* also exhibit the strong development of the external cingulum and its cusps, the para-, meso-, and metastyle, which are foreshadowed in the Jurassic mammals and become extremely developed in the related Upper Cretaceous genus *Thlæodon*,

as well as in many modern polyprotodonts. These external cingulum cusps were rightly regarded by Winge as being a very ancient part of the mammalian molar crown.

The genus *Thlæodon*, a contemporary of *Eodelphis*, is regarded by Mathew (1916) as a specialized phase of the same family (Cimolestidæ). The jaw has become much larger, attaining an estimated length of about 80 mm. The posterior premolars, both in the upper and lower jaws, have become greatly worn, and have blunt tips somewhat like the crushing molars of sea-otters and of other dentitions adapted for crushing and breaking hard substances. The upper molars exhibit an excessive increase in size of two of the external cingulum cusps, probably the para- and metastyle. The lower molars are of the modified tritubercular type with moderately well developed talonid. The angular process is inflected as it is in *Didelphys* and modern polyprotodonts.

Thus, these Upper Cretaceous polyprotodont marsupials, which, in common with the placentals, may have been derived from the Lower Jurassic Amphitheriidæ, were even in their time widely separated from the placentals and had already developed a considerable adaptive radiation in the dentition. The more primitive members (*Eodelphis*) seem to be directly ancestral to the modern Didelphiidæ of North and South America, and were also probably related to the Upper Cretaceous European and Asiatic polyprotodonts that were ancestral to the later Australian members of this group.

VI. THE ORIGIN AND EVOLUTION OF THE MARSUPIALS (CRETACEOUS TO RECENT)

The adaptive radiation of the marsupials into many life habits, and into animals that superficially resemble placental mammals of corresponding habits, has been studied by many naturalists, especially Bensley (1903), who investigated the evolution of the dentition and of the limbs, applying the principles and results that had been gained by palæontologists concerning the evolution of the dentition and limbs of placental mammals.

Although not in the line of human ascent, the marsupials afford many beautiful examples of dental mechanics and of the coadapta-

tion of the upper and lower teeth to diverse food habits, an understanding of which proves helpful in interpreting the evolutionary history of the human dentition.

The more primitive existing polyprotodonts are the comparatively little-changed survivors of Upper Cretaceous marsupials, and the group as a whole stands on a lower evolutionary plane than that of the placentals. In the northern hemisphere, one family, the early Tertiary opossums, which were the little-modified descendants of the Upper Cretaceous *Eodelphis* and its allies, were driven southward before the advancing hordes of placentals and found an asylum in the forests of Brazil, where, with few exceptions, they retained their primitive arboreal habits and the greater part of their ancestral heritage in dentition, skull and skeleton. One of them (*Chironectes*) became semi-aquatic in habit, but retained its primitive carnivorous dentition. Another South American family, the Borhyænidæ, which were probably also derived from arboreal ancestors, early succeeded in developing into a terrestrial and predatory line which closely paralleled the carnivorous marsupials of Australia and some of the earlier carnivorous placentals of North America, but were finally crowded out, about the middle of the Tertiary period, by the invasion of placental carnivores. According to Matthew (1916), the primitive Upper Cretaceous marsupials probably had a wide distribution in the northern continents which formed their original center of dispersal. After the ancestors of the Australian marsupials had reached that continent, possibly in the early Tertiary period, the region became severed geographically from the rest of the world, and the higher placentals, which were evolving in the northern land masses, were prevented from invading the Australian region. The marsupial stock was therefore free to branch out in many directions and take advantage of the varied environments, in that continent, without suffering severe competition from the more advanced and progressive placentals.

SUBORDER POLYPROTODONTIA

Although little is known of their early history, the living Australian polyprotodonts exhibit a wide adaptive radiation in the dentition. The small Dasyuridæ, in common with the existing Didelphidæ and

with the Upper Cretaceous *Eodelphis*, retain simple triangular upper molars and tuberculo-sectorial lower molars. The triangular spaces between the upper molars receive the trigonids of the lower teeth, while the "protocones," or internal cusps, of the upper molars fit into the basin of the talonids after the manner seen in *Eodelphis*. From this insectivorous-carnivorous starting-point is developed a specialized carnivorous adaptation culminating in *Thylacinus* and *Sarcophilus*, in which the posterointernal side of the upper molars becomes developed into a large shearing blade directed more antero-

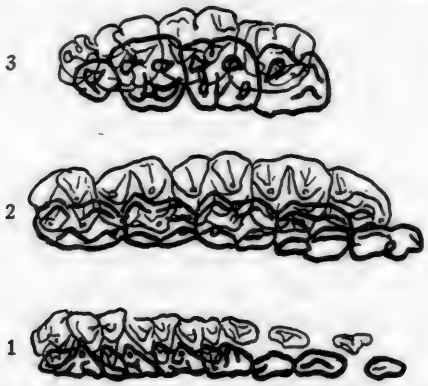


FIG. 39. OCCLUSAL RELATIONS OF UPPER AND LOWER CHEEK TEETH OF MARSUPIALS (COMPARE WITH PLATE II)

1.—*Metachirus* (a small opossum), with tritubercular upper, and tuberculo-sectorial lower, molars. The trigonds of the lower teeth fit into the interdental spaces of the upper; the central fossæ of the talonids receive the tips of the protocones of the uppers; and the hypoconid tips of the talonids fit into the central fossæ of the uppers. The oblique blades on the antero-external sides of the protoconids shear past the blades connecting the metacones with the metastyles; similarly, the transverse blades on the postero-external faces of the protoconids shear past those connecting the paracones with the parastyles. The hypoconids fit between the para- and metaconids.

2.—*Phascolarctos* (Koala). The paraconids of the lower molars have been lost, and the remaining cusps have become more or less crescentic or V-shaped. The talonids have widened transversely, separating the para- and metacones; and the posterointernal parts of the upper molars have grown inward, filling up the interdental spaces and articulating with the talonids.

3.—*Bettongia* (Rat-kangaroo). The quadrate upper and lower molars interlock, much as do human molars in normal occlusion. The lower molars have lost the paraconids, and consist chiefly of four main cusps arranged in two transverse pairs: protoconids, metaconids, hypoconids, and entoconids.

posteriorly than transversely, and shearing past the equally prominent blade formed by the enlarged para- and protoconids of the lower molars. At the same time, the talonids of the lower molars become smaller and with them the internal cusps or "protocones" of the upper molars, so that a perfected shearing action is finally developed. In South America, the Borhyænidæ go through a similar line of evolution, which is also followed even to much further lengths in two or three phyla of placental mammals. In this progressive carnivorous adaptation, the sides of the molar crowns become of predominant importance and the overlapping of the talonid upon the "protocone," or internal spur, of the molars is reduced and finally eliminated. This is the very opposite extreme from the line of evolution followed by omnivorous and herbivorous animals of all orders, in which the crowns, including especially the talonids of the lower molars, and not the sides and the interlocking parts, become dominant in function.

Primitive Australian polyprotodonts, probably of the family Dasyuridæ, also gave rise to an otherwise unknown line culminating in the highly aberrant *Myrmecobius*, or "banded anteater." In this genus the molars are more numerous (five or six on each side above and below) than in ordinary marsupials and are of very peculiar form, elongate anteroposteriorly and greatly compressed laterally. The lower molars are surmounted by three main cusps, so that they have a superficial resemblance to the triconodont type. The jaw and dentition of *Myrmecobius* have often been compared with those of Mesozoic mammals, and some have even expressed the opinion that this animal is a little-modified survivor from the Purbeck fauna. But Bensley rightly concluded that it is only an aberrantly modified dasyurid; that its molars, instead of being primitive, are peculiarly specialized; and that its apparent resemblances with the molars of Mesozoic mammals are largely secondary. In skull structure, *Myrmecobius* is plainly a specialized dasyurid, and it is noteworthy that the incisors, canines and premolars are much less aberrant than the molars; also, that the lower molars bite far to the inner side of the upper, and are directed sharply inward and upward, an anomalous adaptation to insectivorous diet.

In the straightness of the upper and lower tooth rows, which form nearly parallel lines, in the wide spacing between the teeth and in the flatness and length of the palate, the dentition of *Myrmecobius* parallels that of the armadillos.

Assuming the correctness of the conclusion, that *Myrmecobius* is merely a specialized dasyurid and not a close relative of the Mesozoic mammals with which it has been compared, it affords a conspicuous

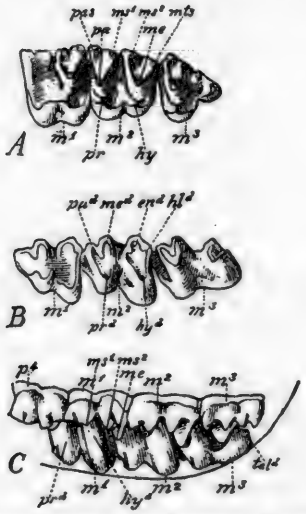


FIG. 40. UPPER AND LOWER MOLARS OF *Peramales*, REPRESENTING A SPECIALIZED DERIVATIVE OF THE TRITUBERCULAR MOLARS OF THE PRIMITIVE DASYURIDÆ
AFTER OSBORN AND GREGORY

The molars are elongate anteroposteriorly and, consequently, divided into distinct anterior and posterior moieties. The enlarged V-shaped talonids fit between the widely separated V-shaped para- and metacones. The trigonid basins receive the hypocones, while the talonid basins receive the protocones.

example of the unreliability of superficial resemblances between molar teeth of widely unrelated types.

The third offshoot of the primitive dasyurid stock is represented by the bandicoots, or Peramelidæ. These small hopping marsupials have narrow feet armed with strong claws with which they dig nests, burrows or holes in the ground. Apparently, more or less dirt must get mixed with their food, which is of the omnivorous-insectivorous

kind, because their molar crowns have become hypsodont, or long-crowned, and have lost much of their primitive tritubercular heritage. The upper molar crowns are quadrangular in outline, the primitive triangle being modified through the outgrowth of the posteroexternal corner of the crown so as to produce a so-called hypocone. It is not certain whether this is a true hypocone derived as in placentals from the posterointernal cingulum, or whether it is an extension of the metaconule, but in either case it fills out the posterointernal contour of the crown and obliterates the triangular space between the adjacent upper molars. It thus fills the space formerly occupied by the trigonid of the lower molar and, consequently, the hypocone now articulates directly with the basin or fossa of the trigonid. The V-shaped para- and metacones of *Perameles* articulate between the trigonids and the talonids of the lower molars, while the "protocones" articulate with the basins of the talonids. Each lower molar consists of two narrow Vs, the higher anterior V formed by the trigonid, the lower posterior V formed by the talonid. These two Vs are well separated because of the inward position of the para- and metacones of the upper teeth. Conversely the prominent V-shaped talonid wedges in between and widely separates the para- and metacones of the upper teeth. Both the upper and the lower molars are wider anteroposteriorly than those of primitive tritubercular dentitions. Thus, the pattern of the molar teeth of *Perameles* (derived according to the evidence of its skeletal structure from primitive tritubercular dasyurids) parallels similar adaptations among various other families of marsupials and placentals, and tends to confirm my view that the separation of the para- and metacones of the upper molars is correlated with the transverse widening of the talonids of the lower teeth, which push in between the lingual slopes of the para- and metacones. The upper molars of *Perameles* retain the primitive external cusps or styles which here, as in other cases, do not articulate with any part of the lower teeth but are abraded by the food which they assist in holding and pressing against the lower molars. The para- and metacones have grown so far inward that they have obliterated the proto- and metaconules, a process which may be observed in various other phyla of mammals.

Thus, the Peramelidæ afford an instructive example of incipient adaptation towards a grinding type of molars, and Bensley regarded their molar patterns as structurally intermediate between the primitive dasyurid and the primitive diprotodont molar types.

Another line of adaptation which has been derived from the primitive dasyurid is that of the "marsupial mole," *Notoryctes*. At first sight this animal appears to have almost pure tritubercular lower molars, which one might wish to derive from the primitive tritubercular lower molars of the Jurassic mammals, as *Dryolestes*, but a study of the skull and skeleton indicates that *Notoryctes* is a specialized derivative of the primitive dasyurids; and, therefore, the total lack of talonids in the lower molars, and the extremely simple tritubercular pattern of both the upper and lower molars, is probably in part secondary, as it is in similar cases among the placental insectivores. It seems very likely that the high apex of the upper-molar crowns is really the paracone, homologous with the single tips of the premolars and with the tips of the molars of *Peralestes*, and that the two large external cusps, commonly called the para- and metacones, are really the para- and metastyles, the real protocone being represented by the so-called internal cingulum. An analogous condition is finally attained among placental insectivores of the zalambdodont or erinaceid group.

SUBORDER DIPROTODONTIA

The Australian diprotodonts, in spite of their wide external differences in form, constitute a fairly compact group united by many peculiar common characters in the skull, limbs, brain, reproductive organs, etc. Bensley, following the suggestions of Huxley and Dollo, has shown very fully that the diprotodonts represent an evolutionary advance upon the primitive polyprotodonts. With regard to the dentition there is a considerable structural hiatus between these two groups, so that, if it were not for the strong evidence afforded by the rest of the anatomy, it would be unsafe to assume the derivation of the diprotodont molars from the primitive dasyurid type. But this evidence is so strong that there can be little doubt of such derivation of the molar patterns.

The more primitive molar patterns are preserved by some of the omnivorous-herbivorous phalangers, in which the upper molar crown consists chiefly of four obtuse Vs arranged in two parallel rows and facing outward, with their apices directed inward. These apices are named protocone, paracone, metacone and hypocone. The external cingulum cusps are greatly reduced or absent. In the lower molars the trigonid and talonid, although considerably disguised, may still be recognized and consist of (a) two external Vs, representing the protoconid and hypoconid, and (b) two internal loops with the concavity directed outward, representing the metaconid and the entoconid, the paraconid being reduced or absent. This relatively primitive pattern is adapted for a combination of cutting, breaking, and grinding. The outgrowth of a hypocone having greatly reduced the spaces between the upper molars, the overlapping relations with the lower molars are correspondingly emphasized.

From this comparatively central type, Bensley derived, *first*, that of the koala (*Phascolarctos*) by the further emphasis of the V-shaped or crescentic character of the four main cusps, so that both the upper and lower molars bear four distinct Vs, or crescents, facing outward in the upper and inward in the lower molars. This crescent-shaped pattern has often been evolved among the placentals in adaptation to leaf-eating habits. The *second* line of derivation from the primitive diprotodont type leads to the molars of the kangaroos and their allies, in which the summits of the opposite cusps have been linked by prominent cross-crests developed on the slopes of the four main cusps, so that they produce a tapiroid or bilophodont type of molar. The talonid, as in all such "lophodont" types, has become greatly developed. This bilophodont pattern is paralleled not only in the tapirs and various other ungulates, but also in the monkeys of the Old World.

Perhaps the most specialized derivative of the primitive diprotodont pattern is seen in *Phascolomys*, with its beaver-like skull and dental apparatus. There is a single pair of gnawing incisors growing from persistent pulps in both the upper and lower jaws, followed by a wide diastema. The cheek teeth are hypsodont, consisting of two V-shaped columns. Many analogies with rodents are evident, but the marsupial nature of the animal is revealed not only by the brain,

reproductive organs, etc., but by the underlying characters of the skull and lower jaw, a long list of which agrees with those of less specialized diprotodonts.

In spite of the highly specialized dentition, *Phascolomys* and its allies are doubtless related to the koala (*Phascolarctos*), and their

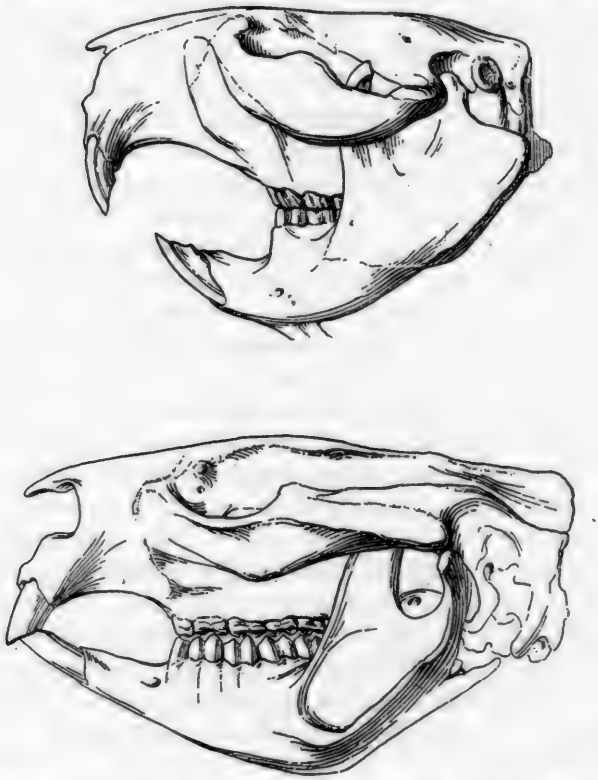


FIG. 41. SIMILAR ADAPTATIONS FOR GNAWING AND GRINDING WOODY TISSUE IN THE WOMBAT (*Phascolomys*), A DIPROTODONT MARSUPIAL, AND THE BEAVER (*Castor*), A RODENT PLACENTAL

The side view shows well the enlarged median pair of incisors in both upper and lower jaws, the long diastema behind them, and the long-crowned cheek teeth.

In spite of its rodent-like appearance, the skull of *Phascolomys* preserves much of its "heritage" of primitive marsupial characters, such as the strongly inflected angles of the mandible.

columnar molar teeth have probably been derived from the crescent bearing molars of the koala.

The case of *Phascolomys* is highly instructive. If we were dependent solely upon a comparison of its dentition with that of other known mammals, we could hardly infer either its real affinities or the evolu-

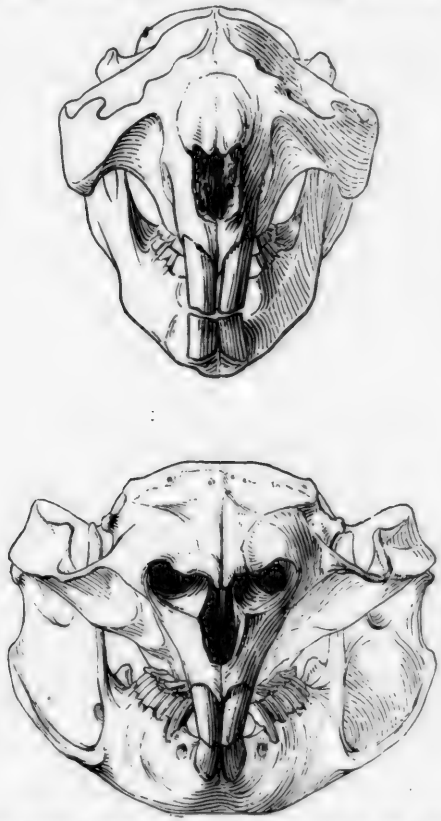


FIG. 42. FRONT VIEW OF SKULLS ILLUSTRATED IN FIGURE 41

tionary history of its dentition. By a study of the rest of its anatomy, however, in comparison with that of other marsupials, we determine its real relationships; and, by analogy with numerous well-established cases among the placentals, we find that the assumption of a rodent-like dentition, or of the hypsodont condition of the molars, rapidly effaces the primitive tritubercular heritage.

VII. SUMMARY AND CONCLUSIONS FOR PART I

Owing to the well-known "imperfection of the palæontological record," and to the vast chronological extent of vertebrate evolution which must be reckoned at least in tens of millions of years, the known stages of ascent are seldom in the direct relation of ancestor and descendant. Nevertheless, the broader features of the evolution of the dentition, leading eventually toward the mammalian and human types, appear to be well established.

In the earliest known stage, represented by the ostracoderms of the Upper Silurian and Devonian, the food was possibly engulfed by the capacious oral hood, or drawn in by the pumping action of the nascent branchial apparatus; but neither teeth, cartilaginous jaws, nor gill arches, had yet been evolved. These elements were first differentiated in the primitive sharks of Silurian and Devonian ages, the primary jaws (palato-quadrate and Meckel's cartilage) being merely enlarged and further modified members of the series of branchial cartilages, operated by muscles which are serially homologous with those of the branchial arches and provided with teeth derived from the infolding of the dentigerous skin around the borders of the mouth. True bony tissue had not yet been developed, but the endoskeleton was strengthened by calcific deposits in the cartilage. These primitive vertebrates were active predatory fishes of immense evolutionary potentialities, since they embody the structural ground plan of all the higher classes.

The next stage of ascent is illustrated in the primitive ganoid fishes of the Devonian age. In these the primary, or cartilaginous, jaws had become ensheathed in bony skin-plates. The teeth are now confined to the margins of the jaws and the roof of the mouth, instead of covering the whole body, as in sharks. The skin on the head gives rise to the external or dermo-cranium; and that on the body to the scales and dermal rays. True bone cells have thus invaded the skin and also extended to the cartilaginous endoskeleton, which they finally replace. Of these primitive ganoids one line, known as the Actinopterygii, becomes more and more highly ichthyized, or adapted for typical fish-like habits, and thus removes itself from the line of human ascent.

The second line, the Dipnoi, are less successful as typical fishes, but develop lungs which supplement the gills in oxygenating the blood. This group, however, is very early eliminated from the main line through the overspecialization of the dentition, which takes the form of fan-like clusters of denticles on the roof of the mouth and on the inner sides of the lower jaw. A related group, the Crossopterygii, share with the dipnoans the possession of lungs, which were naturally prerequisite for ancestors of the air-breathing tetrapods, but they avoid excessive specializations of the dentition, and, preserving their primitive predatory habits, they retained simple, unfused, teeth on the margins and inner sides of the jaws and on the roof of the mouth. Their teeth have elaborately infolded bases and are essentially identical in construction with the labyrinthodont teeth of the earliest four-footed vertebrates. Perhaps this infolding of the bases of the teeth served to strengthen the hold of the teeth upon the tough, bony, skin which bore them. A similar adaptation may be seen in the existing garpike, *Lepidosteus*. The crossopterygians also possess the right kind of pectoral and pelvic paddles to give rise to the paired limbs of the primitive tetrapods.

The greatest advances in evolution have always accompanied revolutionary changes in habits and the passage from one life zone to another. The emergence of the primitive tetrapods from the stem of the crossopterygians involved the most profound alterations in the locomotor apparatus, since the adventurous pioneers had to sacrifice the hard won adaptations for a fish-like mode of life, and to learn to support the entire weight of the body in a new medium which gave no aid through its buoyant properties. But, while the changes in locomotor and respiratory apparatus were truly revolutionary, the organs of ingestion and digestion preserved much of their piscine heritage.

As we pass from lower to higher vertebrates there is a steady reduction in the number of different parts,-sometimes accompanied by the multiplication of single parts. So, too, in the passage from the crossopterygian to the tetrapod, there is a marked reduction in the number of bony plates covering the skull and lower jaws, the former losing the opercular series and the latter losing many of the plates on the under side, especially the gular and infradentary series.

The earliest tetrapods still went through a fish-like or tadpole stage of development, which has been retained in modernized amphibians. The latter early removed themselves from the direct line of human ascent by becoming secondarily adapted for living in the water, even in the adult stage and after the development of complete limbs. In these forms, the head becomes broad and depressed through the lateral spreading of the jaws and the failure of the middle part of the skull to increase in vertical depth. At the same time, the primitive tripartite occipital condyle loses its medial portion and becomes confined to the exoccipital bones. The palate, at first closed-over in the midline, opens out and the epiphyses of the limb-bones fail to ossify.

In the primitive reptiles, on the other hand, which were the ancestors of all the higher types of vertebrates, the tadpole stage was early eliminated, the adaptations for quadrupedal progression on land were progressively developed, and the easy descent to secondary aquatic habits, which has tempted many lines away from the upward path, was avoided. The skull, as a whole, became compressed rather than flattened, the brain-case and upper and lower jaws being vertically deepened. The labyrinthodont pattern of the bases of the teeth was gradually lost as the teeth became implanted in distinct sockets.

In the stem reptiles (Cotylosauria) the occipital condyle retains its primitive centrum-like character, and the primitive roofing bones on the occiput and temporal region are preserved intact. Most of the better known cotylosaurs are already too specialized in dentition to be directly ancestral to the higher reptiles, which must have been derived from primitive insectivorous members of the order, perhaps allied with the Captorhinids. The various lines leading to modern reptiles diverged from the primitive stock and from their remote relatives, the mammal-like reptiles, at an exceedingly early period, certainly not later than the Lower Permian. In so doing, they lost many primitive reptilian characters, and acquired new specializations which have often deceived those who expect to find in modern reptiles the clues to the early history of the human dentition.

The earliest stages of the mammal-like series of reptiles are represented in the smaller and less specialized pelycosaurs, or Theromorpha, of the Upper Carboniferous and Lower Permian of North America. In these the temporal region is perforated by the lateral tem-

poral fenestra, lying beneath the junction of the postorbital and squamosal bones and above the jugal. This opening was apparently developed in connection with the activity of the muscles of mastication, the bone being strengthened and reinforced around the borders of insertion of the temporal muscle and weakened or removed in the middle of this area. The effectiveness of such an arrangement is seen by opening and closing the jaws of the modern *Sphenodon;* the bony strips that remain around the lateral temporal fenestræ afford adequate supports for the temporal muscles, while the openings permit the free expansion and contraction of these muscles. In the pelycosaurs, the stout bar of bone below the lateral temporal fenestra, composed of branches of the jugal and squamosal, is the forerunner of the zygomatic arch of mammals.

In the true mammal-like reptiles (Therapsida), at present known only from the Permian of South Africa and Russia, and from the Triassic of South Africa, we observe a great advance toward the mammalian grade of organization involving especially the following changes: (1) a progressive improvement in the respiratory system, as indicated by the final development of a sub-mammalian type of palate, and by the differentiation of the ribs into dorsal and lumbar regions; (2) equal improvement in the locomotor apparatus, pointing towards mammalian conditions, and (3) a progressive evolution of the dentition, beginning with the compressed, simple, recurved teeth of the gorgonopsians and culminating in the diverse and almost mammal-like dentition of the cynodonts. In the Therapsid series, the multiple succession of teeth, characteristic of later reptiles, is not found, as there are but two sets, corresponding to the deciduous and permanent series of mammals. The incisors, canines, and premolars, were replaced by permanent successors, but the molars, although apparently never replaced, are serially homologous with the deciduous series, or exostichos. Replacement was vertical, as in mammals, the permanent teeth pushing out their deciduous predecessors from below, but not becoming intercalated between them as in recent reptiles.

In this group of mammal-like reptiles we find, foreshadowed, many of the fundamental inter-relations of the upper and lower teeth that are preserved in primitive mammals: thus, the upper set bite outside of the lower set and, at least in the more advanced types, each lower

tooth articulates with two uppers. In the primitive cynodonts the cheek teeth are compressed and serrate, remotely suggesting the triconodont type, but differing in that each tooth is supported by only one root. In the nearly related *Diademodon* and its allies, the upper cheek teeth become widened transversely through the inward growth of the basal portion of the crown and root. At the same time the crowns of the lower molars exhibit a tendency to be divided into an anterior moiety, foreshadowing the trigonid of mammals, and a posterior moiety, possibly homologous with the talonid. Thus, in this very early stage, the upper and lower teeth are very unlike each other in form. Nevertheless, it is probable that *Diademodon* and its allies were not directly ancestral to any of the mammals, as their dentition does not appear to lead to any of the later types.

All the cynodonts are very progressive toward mammalian conditions in the construction of the lower jaw, since they have a mammal-like dentary with a wide ascending ramus, although they had not yet established a secondary contact between the dentary and squamosal,[4] while the posterior jaw elements (quadrate, articular, etc.) still functioned for the support of the jaw and for the attachment of the reptilian pterygoid muscles. They were also connected with the auditory apparatus, since the stapes is known to have been in contact with the quadrate, while the tympanic membrane was probably stretched upon the posteriorly forked angular bone (Watson, Palmer). The inner side of the dentary was deeply grooved for the reception of the primary lower jaw, consisting chiefly of the articular bone. The main jaw muscles, as shown by the form of the temporal fossa, and by the shape of the dentary bone and of the zygomatic arch, were of submammalian type. The zygomatic arch differed from that of mammals chiefly in retaining the primitive postorbital bone at its anterosuperior end. Some of the more primitive cynodonts, such as *Ictidopsis* (fig. 9), may have been closely related to the direct ancestors of the Protodonta and Triconodonta of the mammals. *Pachygeneleus*, which is possibly related to *Diademodon*, affords several characters which must be looked for in the ancestors of the mammalian order of Multituberculata.

The fragmentary palæontological record does not reveal the transitional stages between the mammals and the mammal-like reptiles,

[4] See the foot-note on page 106.

and the wide differentiation of the dentition in the few known mammals of the Upper Triassic indicates that the protodonts and the multituberculates were derived from different members of the cynodont reptiles. The protodonts emphasize the characters foreshadowed in the cynodonts with compressed teeth, but differ in the subdivision of the single fang of the cheek teeth into two distinct roots, at least in the molars. The incisors and canines of these animals retain much of their cynodont character and so does the whole dentary bone. Now, however, a secondary contact has apparently been established between the dentary and squamosal, since there are indications of a condylar process on the dentary.

The contemporary multituberculates, on the other hand, had already attained a high degree of specialization, since the lower molars had become "basin-shaped" (*Microlestes*), possibly through the upgrowth of the internal cingulum parallel to the primitive row of low cusps on the buccal side of the tooth. Apparently the posterior premolars had already become enlarged and grooved (*Microlestes rhæticus*). Although the front teeth of *Microlestes* remain unknown, they were probably not dissimilar to those of the later multituberculates, and were thus already enlarged, procumbent, and separated from the cheek teeth by a diastema.

About this time (Upper Triassic), or perhaps somewhat later, the order Trituberculata may already have been differentiated from primitive cynodonts, as it appears to be represented by an imperfect lower jaw (*Karoomys*) from the summit of the Karoo series in South Africa.

In the fauna of the Stonesfield Slate (Lower Jurassic of Great Britain) we find three very distinct orders of mammals, the *first* type of dentition including the primitive triconodonts, *Amphilestes* and *Phascolotherium*, in which each lower molar tooth had a compressed crown with a central apex, and two low cusps on its anterior and posterior slopes. The *second* type is represented by *Amphitherium*, the oldest and most primitive of the order Trituberculata, which exhibits the tritubercular lower molar in its archetypal form. In this genus the incisors, canines, and anterior premolars, are not dissimilar to those of the triconodonts. All the cheek teeth, likewise, are supported by two roots, and the number of post-canine teeth (eleven) is higher than in primitive placentals and marsupials of later ages. The molar

teeth, however, are tritubercular instead of triconodont, and there is no evidence that, in this early stage (Lower Jurassic), the tritubercular pattern had been derived from the triconodont. On the contrary, it seems probable that the paraconid, metaconid, and entoconid, arose *in situ* on the slopes of the protoconid, and were not derived through the "rotation," or circumduction, of the lateral smaller cusps of a triconodont crown. Moreover, the jaw differs considerably from that of the triconodonts, inasmuch as it has a primitive uninflected angular process like that of the earliest placentals. Hence, this earliest known and most primitive trituberculate affords no support for the famous Cope-Osborn hypothesis of the origin of the tritubercular molar pattern, which was based on conditions observed in mammals of a later period. The *third* order (?Multituberculata) is obscurely represented in this fauna by the fragmentary jaw called *Stereognathus*.

From the Lower Jurassic of South Africa the genus *Tritylodon* is literally multituberculate, since each upper molar tooth bears three rows of cusps, but this form is very unlike any other member of the order to which it doubtfully belongs. It serves to emphasize the extremely early differentiation of the multituberculate type of teeth, and to indicate the wide separation of this group from the tritubercular and triconodont mammals.

In the Purbeck and Morrison faunas of Upper Jurassic age we find the same three orders, Multituberculata, Triconodonta, and Tritubercula, but in a more advanced stage of evolution. The multituberculates are now represented by the family Plagiaulacidæ, which are differentiated by the great development of the compressed, grooved, lower premolars and the small size of the lower molars.

At that time (Upper Jurassic) the normal triconodonts apparently reached the end of their evolutionary span. They exhibit, first, a reduction in the number of true molars, concomitant with an increase in the anteroposterior diameter of each molar and, secondly, the final stage in the production of a pure triconodont crown, with three equal cusps placed in a single fore-and-aft line. In certain aberrant triconodonts (*Menacodon*, *Tinodon*), the accessory cusps on the slopes of the protoconid are displaced toward the inner side of the crown, and it is possible that this line gave rise to the Spalacotheriidæ, in which

the three primitive cusps are finally arranged in an equilateral triangle with the apex (protoconid) on the buccal side. It is also possible that, in some of these, the triad of cusps became asymmetrical, giving rise to the conditions, in *Leptocladus* (*Peramus*) and related genera, which have been referred to the Trituberculata. Here, in substance, is the whole evidence for the Cope-Osborn hypothesis of the origin of the trigonid through the rotation or circumduction of the accessory cusps toward the inner side of the protoconid. But, as we have seen, this would only account for the origin of the trigonid in certain genera which may well be pseudotrituberculates, and its force is lessened by the wide difference between the tritubercules and the triconodonts in the earlier Stonesfield Slate fauna. It was definitely recognized by Osborn, in 1888, that the tritubercular type may have been derived more than once and in different ways, but his opponents have forgotten this; and, by endeavoring to overthrow the "cusp-rotation" hypothesis, have imagined that they have undermined the whole theory of trituberculy.

The true Tritubercula of the Purbeck and Morrison faunas include a considerable variety of forms ranging from the more primitive *Amblotherium*, possibly a descendant of *Amphitherium*, with more normal tritubercular molars, to the stylodonts, which have high, styloid, molars with three sharp pricking cusps, and with an apparently secondary reduction of the talonid and more or less coalescence of the two main roots. In *Amblotherium* the incisors, canines, and premolars, remain very primitive, the latter having high compressed crowns, the apices of which are undoubtedly homologous with the protoconids of the molars. The lower jaw closely resembles that of *Amphitherium* and has a distinct angular process of primitive placental type.

There are several types of upper molars among the Purbeck tritubercules, of which the association with the lower molars has been more or less in doubt. A conclusion reached in this paper is that Owen was right in associating the upper teeth of the animal named *Peralestes* with a lower jaw having teeth resembling, in many respects, those of *Amblotherium*, *Achyrodon*, and *Peraspalax;* in other words, that *Peralestes* represents the upper dentition of the Purbeck successors of *Amphitherium*. In this genus, with its irregularly trigonal

upper molars, the high apices of the molars are evidently homologous with those of the premolars. The upper molars of the stylodonts (*Kurtodon*, *Dryolestes*) are very narrow transversely and unlike those of *Peralestes* in appearance, yet they also have the high internal apex serially homologous with that of the premolars. A third type of upper molars, seen in *Diplocynodon*, is very aberrant. The internal apices are greatly expanded anteroposteriorly and connect with the external apices by low transverse crests. The homologies of the parts in this type of molar are doubtful. In the more normal trigonal upper molars of *Peralestes* and *Kurtodon*, there are interdental spaces for the reception of the trigonids of the lower teeth. On the inner side of the upper molars of *Dryolestes*, an internal cingulum at the base of the crown may foreshadow the lingual process which becomes highly developed in the molars of later types and gives rise to the so-called protocones.

In the typical Amphitheriidæ there are eleven post-canine teeth, which are short in the anteroposterior diameter. In typical later mammals (marsupials and placentals) the number of post-canine teeth is reduced to seven, but each molar has its anteroposterior diameter considerably increased through the great development of the talonid. Apparently, this process occurred in the later part of the Age of Reptiles, because the opossum-like marsupials of the Upper Cretaceous already have well developed talonids which receive the expanded protocones of the upper molars. The latter appear to be homologous with the internal extensions from the base of the crowns of the premolars, and likewise the para- and metacones have every appearance of serial homology with the tips of the premolars. The transverse expansion of the talonid of the lower molars presses the hypoconid against the lingual slope of the original apex of the crown and apparently conditions its division into two cusps, para- and metacone, which moved apart anteroposteriorly in proportion to the buccal growth of the hypoconid. The V-shaped proto- and metaconules are developed on the anterior and posterior slopes of the protocones, shear past the external faces of the trigonids, and fit into the V-shaped reëntrant valleys left between the trigonids for the fully developed talonids of the lower teeth.

The primitive marsupials of the Upper Cretaceous exhibited a considerable adaptive radiation in the dentition, ranging from tritubercular forms, adapted for a carnivorous diet, to animals in which the molar and premolar crowns were surmounted by massive, swollen and blunt cusps, possibly adapted for breaking and crushing the shells of invertebrates. The modern marsupials of Australia and South America are probably specialized descendants of the Upper Cretaceous "opossums," which were contemporaries of the last of the great reptiles.

The adaptive radiation of the dentition of marsupials was first fully worked out by Bensley, by applying the principles of dental evolution deduced from the better known palæontological record of the placentals. It also affords an illuminating example of the diverse inter-relations of the upper and lower teeth in carnivorous, omnivorous, and herbivorous, types of dentition. In the carnivorous types, the shearing blades on the sides of the upper and lower crowns become greatly emphasized and are shifted from a transverse to a more anteroposterior position. At the same time, the talonids of the lower molars and the so-called protocones of the upper molars become progressively reduced and the para- and metaconids approximated. In the herbivorous types, on the contrary, the talonids are progressively developed, overlapping broadly on the crowns of the upper teeth; by the development of crests on the crowns of the upper and lower molars various effective combinations for cutting and crushing are produced. The filling out of the quadrate contour of the crown, through the upgrowth of the hypocone, accompanies the anteroposterior elongation of the tooth, and, obliterating the interdental spaces, effects an overlapping of the hypocones of the upper molars into the basins of the trigonids of the lower molars.

Thus, the marsupials parallel the placentals in dental evolution as well as in body form and habits, and a clear understanding of the mechanical relations of the parts of their upper and lower teeth will be helpful to students of the human dentition.

(End of Part I)[5]

[5] The manuscript of the second part of this review has been received for publication in the next succeeding issue of this JOURNAL. The bibliography will be appended to the concluding part, in the December issue.—(Ed.)

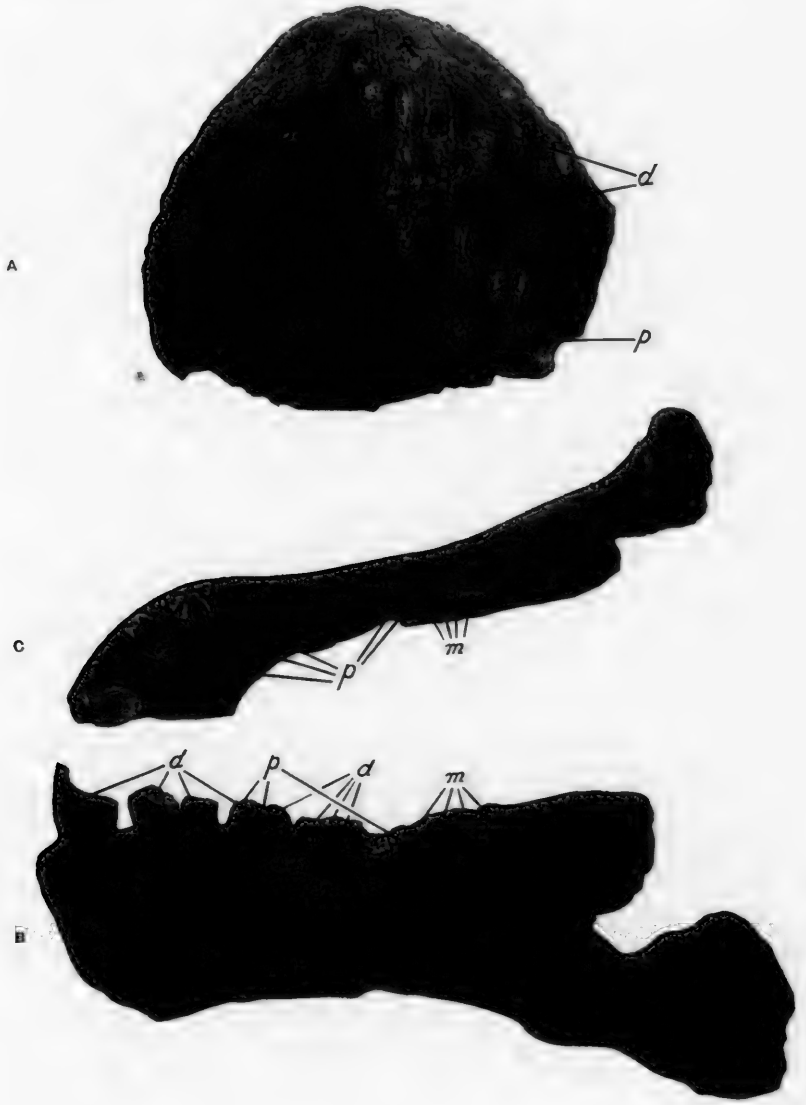
PLATE 1

Upper and lower jaws of mammal-like reptiles from the Permian of South Africa, showing deciduous and permanent teeth.

A.—Front view of upper and lower jaws of *Taurops macrodon* Broom (Amer. Mus. Nat. Hist., no. 5,610), showing the deciduous upper and lower teeth (*d*) in occlusion, and, in the lower jaw, the unerupted permanent teeth (*p*) beneath the deciduous series.

B.—Right mandibular ramus of *Moscognathus whaitsi* Broom (Amer. Mus. Nat. Hist., no. 5,602), showing the deciduous series (*d*) in place and some of the permanent teeth (*p*) directly beneath them. The molars (*m*), in the back part of the jaw, belong to the exostichos, as do also the deciduous teeth, but apparently were never replaced.

C.—The same (B), seen from above.



(Gregory: Evolution of the Human Dentition)

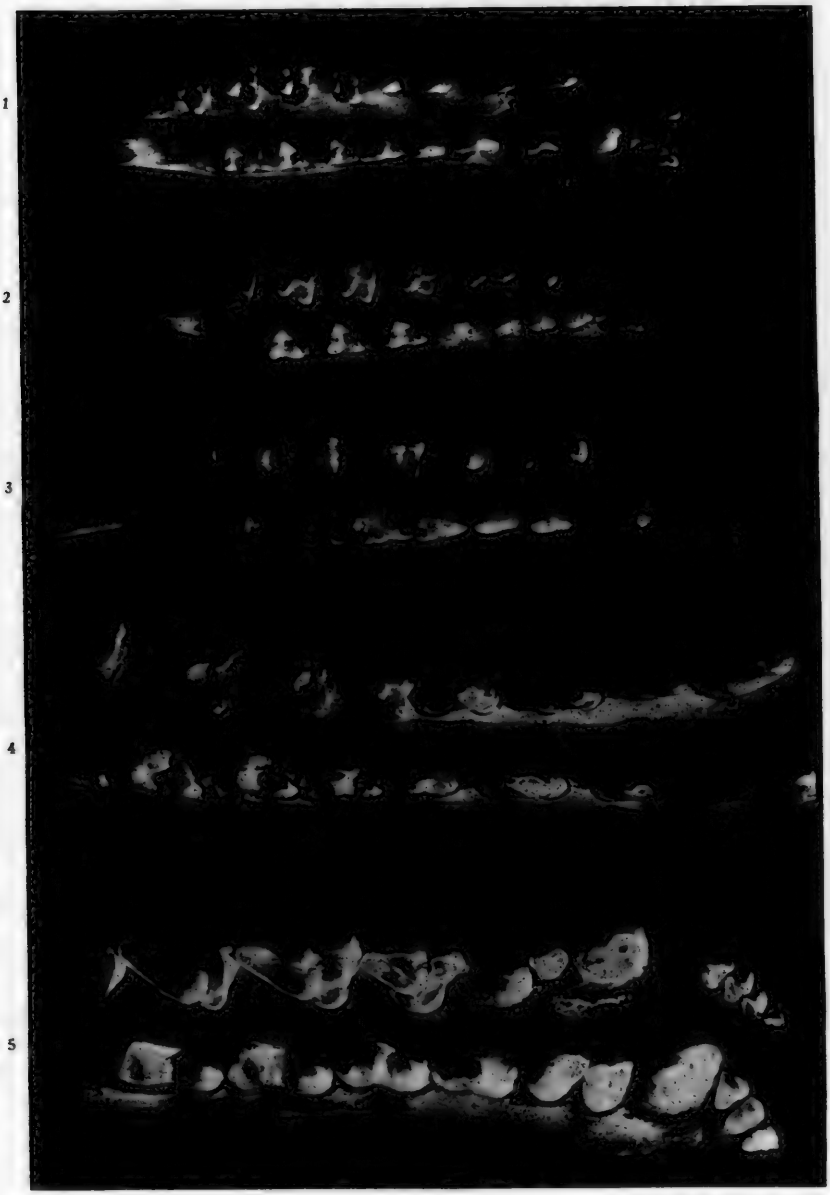
PLATE 2

Teeth of insectivorous and carnivorous polyprotodont marsupials, arranged to indicate the functional relations of the parts of the upper and lower molars (cf. *fig. 39*). Specimens in the American Museum of Natural History.

1.—*Metachirus*, × 2. 2.—*Phascogale*, × 6. 3.—*Dasyurus*, × 2. 4.—*Thylacinus* × 1. 5.—*Sarcophilus*, × 3/2.

In the most specialized carnivorous type (5), the shearing action of the anterior blades of the trigonids is greatly emphasized; while the talonids of the lower, and the "protocones" of the uppers, are correspondingly reduced.

In any dentition the upper teeth, in occlusion, face downward and the lower teeth upward. Therefore, their images, if projected onto the plane of the paper, would fall on opposite sides of it. As the paper is opaque and we wish, nevertheless, to represent both upper and lower teeth on one side of it, and at the same time to indicate the occlusal relations, we must present a direct image of, say, the left uppers in association with an inverted image of the left lowers. In practice we may obtain this effect, as in *plates 2–4*, by using a direct image of the left uppers in association with a direct image of the right lowers, since the crown view of the right lowers gives substantially an inverted image of that of the left.



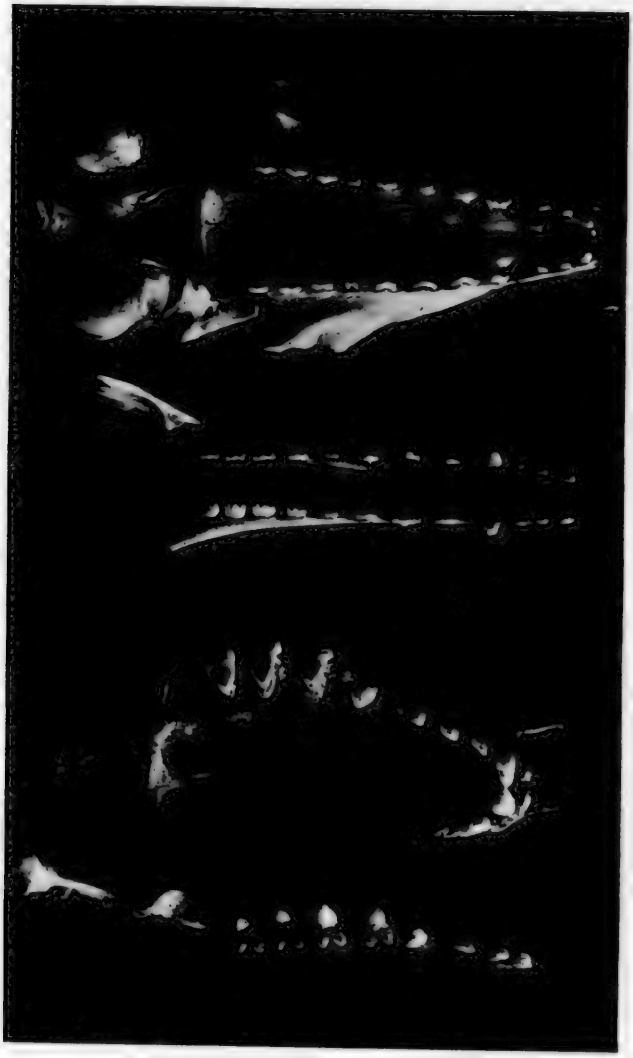
(Gregory: Evolution of the Human Dentition)

PLATE 3

Aberrant types of dentition among the polyprotodonts, derived apparently from the primitive dasyurid type. Specimens in the American Museum of Natural History.

1.—*Myrmecobius*, "banded anteater." The teeth are modified in connection with anteating habits. The molars have increased in number and, becoming elongate, have lost their primitive tritubercular character.

2.—*Notoryctes*, the "marsupial mole." The teeth are modified, perhaps, in connection with worm-eating habits. The "tritubercular" form of the teeth is probably secondary, and may have arisen, as in the last molars of *Dasyurus* and *Phascogale* (*plate 2, fig. 2, 3*), through the reduction of the talonids and the loss of the paracones.



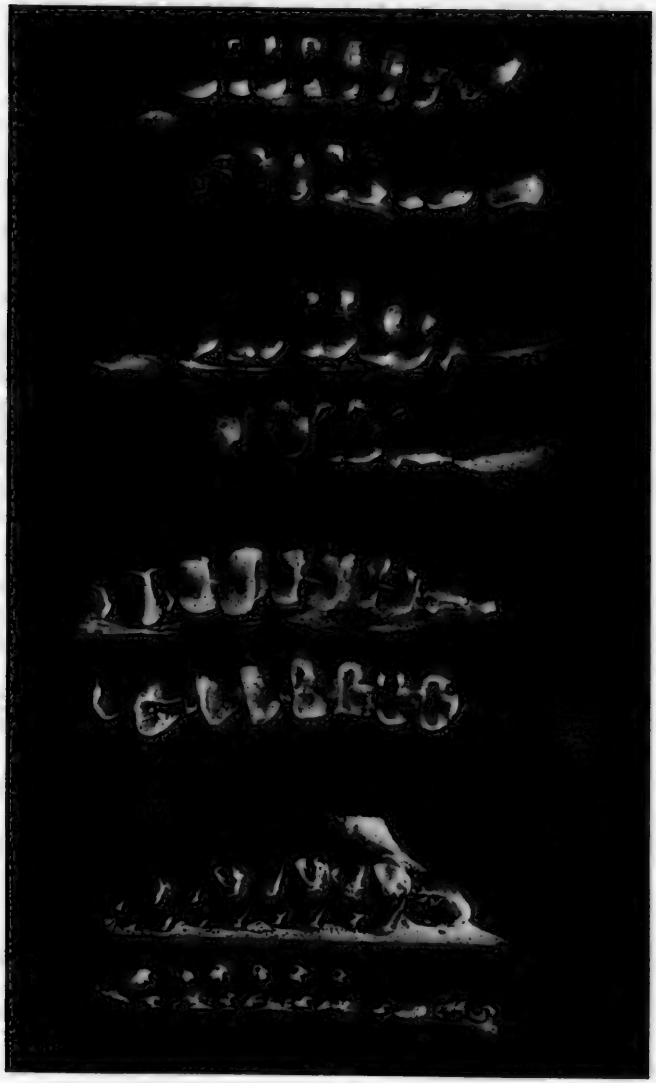
(Gregory: Evolution of the Human Dentition)

PLATE 4

Teeth of omnivorous, herbivorous, and leaf eating diprotodont marsupials. Specimens in the American Museum of Natural History. See remarks under *plate 2*.

1.—*Phalangista*, phalanger, × 2. 2.—*Bettongia*, rat-kangaroo, × 3. 3.—*Macropus*, kangaroo, × 3/2. 4.—*Phascolarctos*, koala, × 3/2.

The upper molars are now elongate anteroposteriorly, and divided into subequal anterior and posterior moieties, each bearing either a transverse crest or a V. The interdental spaces are now filled out and the surfaces of the crowns articulate with each other, the crests of the upper and lower alternating.



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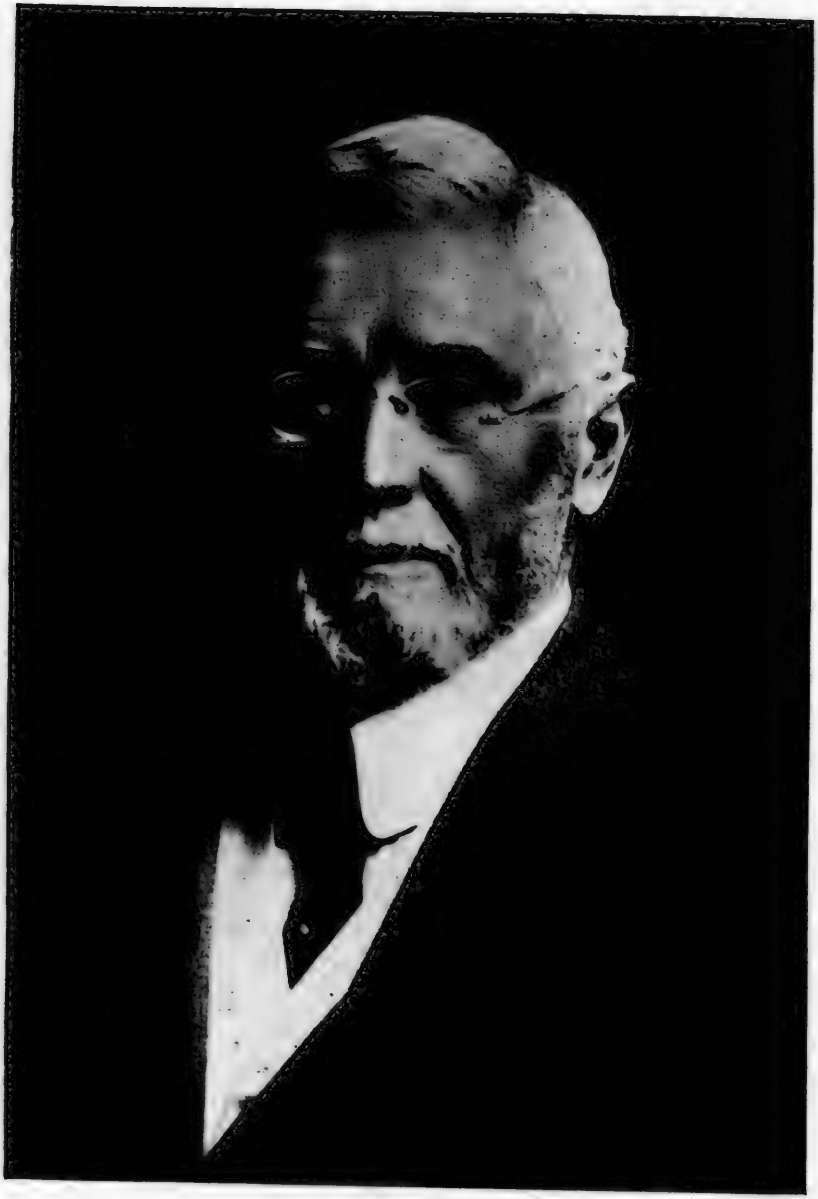
(Gregory: Evolution of the Human Dentition)



A. S. Jenkins.

NEWELL SILL JENKINS

An Appreciation

EDWIN T. DARBY

Philadelphia, Pa.

The subject of this sketch died suddenly in the harbor of Havre, France, on an outward bound passage to Europe, September 25, 1919.

Dr. Jenkins was born at Falmouth, Massachusetts, December 29, 1840. He was the son of Charles Weston Jenkins and Phoebe (Bishop) Jenkins. He received his early education in Farmington School, Maine.

His ancestors were ship-builders and ship-owners. In his youth he had a strong predilection to follow the sea, which arose partly from a strong desire for adventure. In all probability this desire would have been gratified but for the wish of his mother that he engage in some occupation less fraught with danger. Accordingly he turned his attention to dentistry and entered the Baltimore College of Dental Surgery, graduating therefrom in the spring of 1863. He began practice at Bangor, Maine, where he remained for a short time.

At the close of the Civil War he went to Berlin, Germany, where he associated himself with Dr. Francis P. Abbott who was at that time well established in the German capital. His relations with Dr. Abbott were most happy; and the friendship thus formed was of the most intimate character and lasted throughout the life of Dr. Abbott. In casting about for a permanent field of endeavor Dr. Jenkins was encouraged by Dr. Abbott to make his home in Dresden, as at that time the field was an open one for a progressive American dentist. Acting upon this suggestion Dr. Jenkins removed to Dresden and there remained for forty-five years.

Dr. Jenkins possessed all the characteristics which make for success. He very soon acquired a large practice, and numbered among his clientele many of the nobility and crowned heads of Germany,

Russia, Austria and Italy, beside being one of the best known American dentists of the world. He received from the King of Saxony the title of "Geheimer Hofrat," which is one of great distinction. He was also decorated with the Albrechtsorder by the King of Saxony. His services were in such demand in other countries that he spent a month of each year in both Vienna and Warsaw. Few dentists in any country have conducted so large a practice and over such a long period of years. Possessing skill of a high order and a personality most delightful, he not only attracted people from all parts of Europe, but Americans, who made their homes in foreign countries as well as those visiting Germany, sought his professional services. He kept in touch with the latest of American methods of practice and was on intimate terms with members of the professions in his native country.

He was perhaps most widely known to the dental profession as the inventor of "porcelain enamel" or better known as the "porcelain inlay." With a desire to bring this to a degree of perfection he devoted his energies and spent hundreds of hours after laborious days at his operating chair. He was greatly assisted in these experiments by Mrs. Jenkins, who made hundreds of formulas combining materials, colors and shades to meet the requirements of the perfect inlay. It was partly in recognition of this great work that, on his seventieth birthday, the American Dental Club of Paris tendered him a banquet at which representatives of practically every dental society of Europe, England and America were present, and gifts of almost every description were showered upon him. If he was not an active member he was made an honorary member of every national dental society of Europe as well as of Great Britain and the United States. Dr. Jenkins was always a ready writer. Notwithstanding his laborious practice he took time to prepare articles, for the dental journals, which were of a high order and read with unusual interest.

But it was not alone as a professional man that Dr. Jenkins's life was interesting and important, and replete with acts of greatness and goodness. He had not been long a resident of Dresden before the large American colony resident there discovered that a gentleman of refinement and culture had settled among them, and he was accorded a prominent place in the social and intellectual habits of that

colony. He was much sought after in all functions pertaining to the reception and entertainment of visitors of importance from America and elsewhere. Although he never renounced his American citizenship, he mingled freely with the German people and was highly esteemed by all and greatly beloved by many. The cordial greeting which the writer often observed that Dr. Jenkins received at the hands of the citizens of Dresden was evidence of the high regard which they entertained for him.

Dr. Jenkins's homelife was ideal. Many years ago he was fortunate in being able to purchase at Loschwitz, five miles distant from Dresden, a most beautiful villa with twenty-five acres of land enclosed by a high stone-wall. This property was formerly owned by a pupil of Thorwaldsen. The owner was a sculptor of note and had spent some years in St. Petersburgh, Russia, where he had executed in marble in the Winter Palace the frieze of the triumphal march of Alexander the Great into Babylon. Returning from Russia he had laid out these grounds and built a large and elegant house of Italian design. In these grounds he had also built beautiful little studios, while fountains and statues of marble and bronze added beauty to the place. In the large living room at Thorwald—for that was the name given to the villa—the sculptor had produced a replica of the wonderful frieze first made for the Winter Palace. At the death of the former owner this place came into possession of Dr. Jenkins, and it was there he entertained his friends and acquaintances.

Any one who has been a guest at Thorwald will long remember the genuine hospitality and affectionate regard which was extended by both the host and hostess. One could not be long with Dr. Jenkins without noticing a spirit of friendliness which was manifest toward everything about him. The horses that waited at his door to take him to the city were each morning looking for the lump of sugar which he carried in his pocket for them. The dog also awaited a friendly word from his master, which he was sure to get. Dr. Jenkins's spirit was one of kindliness and helpfulness, which was evident in so many ways. When he became interested in porcelain enamel he was entering a field almost unknown to him, and he must obtain information from every source possible. The glass factories and potteries of Saxony afforded him facilities which other localities

did not possess. Among those to whom he applied for information was an old Bohemian glass-blower who had become very skillful in the making of glass flowers. Dr. Jenkins made known to him his special field of research and he found the old man most ready and willing to impart any information he possessed. And then Dr. Jenkins said to him: "Cannot I do something for you in return for this information?" Whereupon the glass-blower opened his heart to Dr. Jenkins and told him that he was sending all of his best flowers to Harvard University in America but that his lack of knowledge of English made it difficult to conduct business relations with his American purchasers and that he would be glad of some help in that line. Dr. Jenkins straightened out his accounts, forwarded a bill for deliveries already made and in due time a draft for several thousand dollars was received. Nor was this all. Dr. Jenkins assisted him in obtaining other and larger orders which enabled the glass-blower to send nearly his whole production to America at greatly increased prices.

Dr. Jenkins's life was one of helpfulness. Those who knew him best have told me that almost daily he did some act of kindness which would help others. Especially was this true in regard to his own countrymen. He never lost his love and deep interest for America; and although he had spent more than half his life in Germany, his interest in international affairs was as keen as when he first went abroad.

He numbered among his friends many of the most eminent men in every walk of life. Baron Holstein of the German Imperial Foreign Office often consulted him in regard to American affairs. Dr. Jenkins was ever solicitous that other nations should understand our disinterested aims. He published many articles in German papers during the Boer and Spanish wars, when feeling against America and England was intense. He took intense interest in the near eastern question—the emancipation of the Christian races—repeatedly visiting Turkey, Greece and the Balkans, the bearer of letters of introduction to their sovereigns.

After Dr. Jenkins retired from active practice he spent considerable time in Paris, often visiting his home in Dresden. When the world war was started he was at Loschwitz and it was his intention to remain there until the end of hostilities.

Under date of November 20, 1914 (forty-eighth anniversary of his first arrival in Dresden) the following extract appears in his diary:

"We arrived in time to observe with intense interest and sympathy the construction of the North German Bund. Later we applauded the superb national spirit through which the union of all the German states was consummated in 1870. Since then we have rejoiced in the rapid growth of German industries and the extent of her commerce throughout the world; and now we ask ourselves, are these great triumphs of German genius to be vastly extended by force and is Germany to find her way to legitimate victory through complete military defeat? What could this people not do were they not possessed by the mania of military conquest? They have convinced themselves that their cause is just, yet they have no friends except Austria and Turkey. The military system by which the whole male population was trained for the defence of the country was originally the result of true patriotism but now, having become the chief passion of the nation, it is working its own ruin. It does not seem possible that Germany can win, for the interests of all the world are opposed to her domination. We are witnessing the conflict of forces the issue of which no man can clearly see, but we can only hope and pray that when this diabolical strife has passed a workable system may be evolved under which all nations shall be obliged to live in peace with each other."

It will be seen from the foregoing quotation that Dr. Jenkins, as early as 1914 (soon after the great war had begun), discerned the outcome of the terrible conflict. He had lived so long in Germany that he had almost become one of them in the pride he felt in their wonderful economic resources. He saw in them, as the whole world had seen, a wonderful people but crazed by military power.

He came to America to await the outcome of that gigantic conflict, and remained until it was over and lived to see his prophecy fulfilled. As a true American he could but rejoice at the result, but the sorrow of it all weighed heavily upon him. During those long and dreary five years Dr. Jenkins remained in America, spending most of the time in New Haven, Conn. He mingled somewhat with his professional friends, and was the recipient of a banquet tendered him in that city by the dentists of the United States.

He always took an interest in everything pertaining to his profession. He attended the various society meetings and was always

heard with interest. It was at a meeting of the First District Dental Society of the State of New York, on November 1, 1915, where Dr. Jenkins happened to be in attendance, that Dr. Gies was making a plea for a few hundred dollars for support of the Society's research in bacterio-chemistry. When he had finished his plea Dr. Jenkins arose and announced that he would contribute one thousand dollars to the cause, and forthwith sent his check for that amount. This was characteristic of the man. "He did good deeds with as great secrecy as most men do evil deeds."

The writer cannot close this brief sketch of the life of Dr. Jenkins without paying a personal tribute to his departed friend. He had known him for many years and on two occasions had visited him at his home near Dresden. Dr. Jenkins had the happy faculty of making you feel that he loved you. It was his nature to love. He was a guileless man thinking no evil of his fellow man. In all my intercourse with him he was never known to have said an unkind word of any one. His sympathies were as broad as humanity and his charity covered as with a mantle all the faults and failings of men. His life was spent in acts of kindness and deeds of love.

Dr. Jenkins was married on June 8, 1865, to Miss Clara Elizabeth Upton of Bangor, Maine, who, with his son, Leonard A. Jenkins, and two daughters, Mrs. Nora Cornelius Shear and Mrs. Grace Madeline Gow-Gregor, survives him. His remains are interred in the family burial-ground at Bangor, Maine.

1701 Locust Street

THE JOHN R. CALLAHAN MEMORIAL FUND

T. IRVING WAY

Chairman of the Memorial Committee of the Ohio State Dental Society, Cincinnati, Ohio

GENERAL PLAN

At the December, 1918, meeting of the Ohio State Dental Society, a resolution was adopted to perpetuate the memory of the late John R. Callahan in recognition of his contributions to the science and art of dentistry, and his unselfish devotion to its advancement throughout the many years of his professional life.

The Committee to which this Memorial was referred has decided on the following as the most appropriate, and worthy of the approval of the profession:

(1) A *Bronze Memorial*, to be placed on the grounds of the Cincinnati General Hospital;

(2) A *Callahan Memorial Research Fund*, the income from which to be awarded, from time to time, to the person making the best contribution to the *science and art of root-canal problems*, the fund and award to be under the direction of a committee perpetuated by the Ohio State Dental Society, and the prize to be known as *The John R. Callahan Award.*

The sum necessary, in the minds of the Committee, to carry out the Memorial in its two phases should approximate $10,000, an amount that should speedily be raised in these times when the spirit of giving is universal.

Subscriptions to this fund by individuals or societies will be duly credited, and should be forwarded to the Secretary-treasurer of the Fund.

The members of the Committee are T. Irving Way, *Chairman*, Cincinnati; Henry E. Germann, *Secretary-treasurer*, 719 Gwynne Building, Cincinnati; L. L. Barber, Toledo; Weston A. Price, Cleveland; L. E. Custer, Dayton; and Edward C. Mills, Columbus.

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Miscellaneous subscriptions (individual)	75.00
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All who may be interested are invited to contribute to this fund.

52 Groton Building.

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Fifth Report

WILLIAM J. GIES

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Amount of *payments* received since the publication of the fourth report	645.15
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A complete list of the contributors to this fund, to the end of the year 1919, is given in the section of general matter, including the title page, for volume I.

Contributions to this permanent endowment fund, *in any amounts*, are invited from *all who may be interested in the welfare and continuing success of this* JOURNAL.

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SCIENTIFIC PROCEEDINGS OF DENTAL AND STOMATOLOGICAL SOCIETIES

FIRST SECTION

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Association of the Allied Dental Societies, Inc.

American Academy of Dental Science

Massachusetts Dental Society

Harvard Odontological Society

Boston and Tufts Dental Alumni Association

First District Dental Society of the State of New York

Metropolitan District of the Massachusetts Dental Society

Harriet Newell Lowell Society For Dental Research, of the Harvard University Dental School

Columbia University Biochemical Association

In the case of the last named organization, only the dental and stomatological parts of its proceedings will be published in this Journal.

A standing general invitation is extended to dental and stomatological societies, everywhere, to add their names to the above register.

PROCEEDINGS OF THE FIRST DISTRICT DENTAL SOCIETY OF THE STATE OF NEW YORK

WILLIAM B. DUNNING, *Editor*

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I. GENERAL MEETING

Meeting of the Society, December 1, 1919. Academy of Medicine, New York City. President Frederick C. Kemple in the chair.

Scientific proceedings. *Paper* by Lewellys F. Barker, M.D., LL.D., Professor of Clinical Medicine, Medical School, Johns Hopkins University, and Visiting Physician to the Johns Hopkins Hospital, Baltimore, Md., on "*oral sepsis and internal medicine*" (page 43). *Discussion* by Drs. Henry W. Gillett, Byron C. Darling, N. T. Shields, M. L. Rhein and H. J. Kauffer, of New York City; and Dr. Barker (this page).

DISCUSSION OF DR. LEWELLYS F. BARKER'S PAPER ON "ORAL SEPSIS AND INTERNAL MEDICINE" (PAGE 43)

BY DRS. HENRY W. GILLETT, BYRON C. DARLING, N. T. SHIELDS, M. L. RHEIN AND H. J. KAUFFER, OF NEW YORK CITY; AND DR. BARKER

Dr. Henry W. Gillett (New York City): This address, in my estimation, is one of the red-letter occasions in the history of the dental profession. A member of so important an organization as the Johns Hopkins University Medical School, having come here with an address of this sort, the day of true coöperation between physicians and dentists is not far away. We are making marked progress, and this address registers one of the notable steps forward. If the medical faculties of Baltimore, when Harris and Hayden brought to them the problem of dental education, could have had but a small fraction of Dr. Barker's vision, how wonderfully different would have been the subsequent history of both medicine and dentistry.

The latter part of Dr. Barker's address is so full of examples of coöperation that it is difficult to decide which to discuss. His address strongly reminds me of a phrase, frequently used before this society by our friend, Dr. Robert T. Morris, when he has advised us to maintain our "sense of proportion" in considering these things. Dr. Barker has carefully maintained a sense of proportion. It is very evident, from his address, that he recognizes in all his work the importance of keeping in touch with men who are skilled in dentistry. His emphatic endorsement of the need for coöperation between medical men and dental men, in arriving at conclusions concerning diagnosis and treatment, is a very happy circumstance for us.

A general practitioner of dentistry is not in a position to discuss the systemic diseases that Dr. Barker has mentioned, except as a dental practitioner may come in contact here and there with the dental relationships of such disorders. Any exhaustive discussion of the relationships of the different systemic diseases must come from other types of diagnosticians—from men working in the same field with him. Any remarks I may make must necessarily be from the standpoint of application of the principles he has mentioned, to the problems that confront the dentist.

Dr. Barker brings us a story of what he finds in his daily work; tells us the things that keep coming up in his experience, and how he feels about their relation to mouth conditions. It is, in effect, putting up to us the question: What are you going to do about it? What are we doing, not only in our daily routine as practitioners, but to help along the day of realization, by every dental practitioner, of the need for observance of the principles Dr. Barker has presented.

I think Dr. Barker has been particularly happy in his recognition of the fact that there are dentists of various kinds, just as there are different degrees of proficiency in every profession, his own included. Many of us are familiar with that fact in our own profession. The only members of our profession who do not seem to be familiar with it, are those who are practising the principles and the technic of earlier decades. We still have such men among us. I want to assure Dr. Barker, however, that a very earnest effort is being made, not only to see that the younger men who come into the profession are equipped in the fundamental knowledge that is required to cope with the dental aspects of systemic disease, but also to help to the same end the men who have been in practice for a time and realize their shortcomings. Better than that, I can assure him that the effort to provide such help is recognized and appreciated by dentists in every part of the country. Those of us who are engaged in the effort to set before practitioners opportunities for post-graduate work, are surprised at the number of applications for admission to such courses now coming from Maine to California, from Washington to Florida. From South America, from other foreign countries, from all quarters, there is manifest a wide-spread urge among dentists for more information concerning, and greater ability to prevent, the conditions and effects Dr. Barker has discussed.

I had intended to make caustic remarks concerning some of our own shortcomings; but, after noting the very happy, courteous, and kindly, way in which Dr. Barker has treated us, I have changed my mind. Yet, we must consider some of the things we should prefer to forget. Frankly, we must recognize that a great many of the foci of infection that the medical and dental professions deal with today, are the result of our lack of knowledge as a profession only a short time ago. We must acknowledge that many of the things we criticise today, many of the conditions that we regret to find today, are due to failure on the part of the dental profession to realize the importance of asepsis; or, if we realized it, are due to our failure to practise proper asepsis in relation to one

part of our work—operations in the root canals of pulpless teeth. (The moment I say "asepsis" in that connection, the minds of some of you turn to a recent unfortunate incident in this city, that is still disturbing some of us; and it is necessary to be a bit careful how we phrase our statements lest some of us who talk should also find *our* names in the newspapers.) It seems as if we needed to have, about twice a year in our societies, a heart-to-heart talk about real, practical, effective, asepsis as a preventive measure in our work on root canals—not asepsis accompanied by all the paraphernalia of the major surgical operation, but asepsis in harmony with that practised by other specialists who work in limited domains, as Dr. Barker has so happily phrased it. Unquestionably, if we can arrive at a condition where effective asepsis in the treatment of root canals is practised by every dentist, we shall have few of these septic foci to deal with ourselves, and few for physicians to criticise.

I know, better than you who have listened to Dr. Barker for the first time, because I have read some of his statements along this line, what his attitude is toward the general removal of merely suspicious teeth. It is a great satisfaction to all of you to hear him speak, as he does, of the need for care—of the need for seeing to it that functioning teeth are not recklessly removed—and to hear him say that, in the effort to eliminate infection, we should not go too far, and needlessly establish other disabilities that are as bad as, or worse than, the one we are trying to remove. It is right there that frequently the perplexities of the dental practitioner turn up. It is right there, Dr. Barker, that every practitioner in this room would be glad to have frequently the advice of just such men as you—the opportunity to get just such coöperation from their medical friends as you have advised. There are many instances in which it is difficult to decide upon the right course. In my own practice, if I may be pardoned for citing a personal example, because I can speak of something with which I am familiar—in the cases where I am doubtful as to the wisdom of extraction, I pursue rigidly the course of obtaining bacteriological cultures from the regions suspected of infection. If the bacteriological findings are positive, I endeavor to communicate with the family physician, either by letter or telephone, and tell him what the findings are—that such and such conditions exist, and that I inform him because the knowledge may be of importance in his treatment of the case. Frequently, it is impossible to get coöperation, either because no medical man is in touch with the case, or because, if there is, it is impossible to enlist his help. Dr. Barker has frankly recognized the fact that some physicians are not interested in this aspect of their work.

Then, there is another class of cases, in relation to which I should like very much to hear Dr. Barker's opinion concerning a course of procedure that I have followed. I recall two cases. One of them is a patient of mature years; an active professional man in sound health, in the habit of submitting to frequent physical examinations by competent diagnosticians—usually by one diagnostician so that his examinations are in the hands of a man familiar with his case. He has received, regularly, through a series of years, a satisfactory report from those examinations. The radiograms show about fifteen to eighteen radiolucent areas at the roots of the teeth. It would be a great misfortune to that man to lose all, or even one, of those teeth. It would be a very serious thing to have the dental structures now on those teeth torn out for the sake of finding out whether any of his teeth are infected. I have taken the responsibility in this case of concluding that, since these suspicious conditions have existed for from ten to twenty years, and so long as the patient continues to get satisfactory reports from his physical examination, we should wait for clear evidence of sepsis before disturbing the teeth.

Another similar case is that of a man with known septic conditions on two teeth. It would be a misfortune for him to lose those teeth. He, too, is frequently examined by competent diagnosticians, and he gets uniformly satisfactory reports. There seems to be no evidence obtainable of a condition in his system calling for interference. I have felt in this case also that, to deprive the patient of those two important, functioning teeth, with their two potential foci, was a responsibility I could not face without better evidence that these septic foci are doing harm.

A full explanation of the circumstances has been made to each patient. I should like to ask Dr. Barker whether he feels that, in these cases, my procedure is warranted. Am I on safe ground in trusting the immunity or resistance that apparently exists in each case?

Dr. Byron C. Darling (New York City): Dr. Barker has covered the situation in a very kindly spirit. The comprehensive list of diseases he gave shows the value of removal of foci of infection for the cure of a patient. There are many foci of infection, as Dr. Barker has been careful to mention, and the teeth are not the only parts of the body that harbor them. Each detectable focus of infection must be eliminated. When several foci exist, each must have an influence on the other; and, while one may not be sufficient to cause noticeable symptoms, combinations of such foci may finally be the cause of disease.

Dr. Barker never forgets the teeth. I fear that few internists are as thorough as Dr. Barker is. We must try to coöperate—the medical and the dental practitioners, and the roentgenologist. Speaking as a roentgenologist, I see the end results. Thus, I receive a patient with a joint disease. The question is—what is the cause of the joint disease? Is it infection in his tonsils, his sinuses, or his teeth, or is an old-time gonorrhea responsible for the disorder? The chances are that one of these factors is concerned, and it is probable his teeth are involved.

The practical thing I want to say tonight is, that, if a man has three doubtful teeth and one of them is a close decision, then, a fine balancing of the situation must be made, and the risk must be taken on the side of elimination of the focus of infection and in favor of extraction. That patient should not be allowed to go, for years, to eight or nine other physicians, before evidence accumulates, in incurable disease, to such an extent that at last the focus of infection must be removed—then, perhaps without noticeable benefit.

Let us devise a mode of coöperation whereby each of us in responsible relation to the patient has some responsibility towards the others. If you have the assistance of a roentgenologist, give him a chance to derive benefit from what you learn about the case. If he makes mistakes, discuss them with him, and give him a statement of your final findings. If he has mistakenly advised extraction, let him know that the results of the bacteriological examination and the appearance of the tooth after removal showed that there was no real reason for the extraction. In that way we shall understand each other, and each contribute to the other's experience and education; and in that way benefit will certainly accrue to the patient.

Dr. N. T. Shields (New York City): Dr. Barker has met the profession exactly as a real medical man should. We have been looking for such a man for a very long period, and I congratulate you and myself that at last we have found him.

Dr. Barker attributes neurasthenic cases entirely to septic or focal infection. A paper I read at Minneapolis, before the American Medical Association about six years ago, on this subject, was discussed by six surgeons. Not one of them agreed with my clinical experience that in the majority of cases tic douloureux—facial neuralgia—is caused by

calcification of the dental pulp. Their argument was that, after all the teeth had been extracted without relief, they always relieved the case through the alimentary tract. My argument was that when the physician had exhausted all means of relief, the case should be sent to a dentist, and that every involved dental pulp should be removed and the root canals scientifically filled. When it is impossible for the blood to circulate freely in the pulp, the injury to the latter may be reflected to a part of the head. In a most modest way I wish to call the essayist's attention to this important fact.

Dr. M. L. Rhein (New York City): I cannot let this opportunity pass without extending to the essayist my personal appreciation of his address.

I do not often agree with my friend, Dr. Shields; consequently, I am more than pleased to agree so heartily with him on the question of the etiologic factor in neuralgia. For thirty-five years I have diligently endeavored to find a case of neuralgia that I could definitely trace to an infective source. I have carefully studied many cases, and each has shown an etiologic factor of the kind indicated by Dr. Shields. With my general knowledge of what mouth infections will do, I should not be surprised to find that neuralgia may be due occasionally to focal infection, but thus far I have never been able to make a diagnosis of that character in any particular case.

I was very much interested in Dr. Barker's statement to the effect that all the cases of endocarditis in his experience, in this relation, proved fatal. About four and a half years ago, my physician made a diagnosis of endocarditis, in my own condition, due entirely to a focal infection in the mouth. I could hardly walk upstairs. I made the etiologic diagnosis myself. I removed the cause, and injected about seventeen autogenous vaccines, the last half of them after I reached the Adirondacks. There, for a time, it was absolutely impossible for me to walk to the upper floors of the building in which I was stopping—I had to remain on the lower floors. I came to New York six weeks later, when my physician could hardly believe the facts in the favorable change he saw in my condition. He expected, in place of an absolute recovery, a post-mortem. At an examination he made of me a few weeks ago, he told me my heart was in a very good condition for a man of my age.

I have given the subject of mouth infection a great deal of study for many years. In 1890, when I read a paper before the American Medical Association, I went very carefully into the danger of the absorption of these toxins. In 1894, before the American Dental Association, I introduced a classification of what we speak of today as periodontoclasia (pyorrheal conditions), dividing them into two types corresponding with their etiologic character. This was followed, in 1896, by a paper on "the oral expressions of malnutrition," read before the New York Odontological Society.

Right here I wish to repeat a word I have spoken often in these meetings, on the importance of the differentiation in mouth conditions between focal infection and other forms of mouth infection—a focal infection being, as I understand it, a limited infection in the alveolus where drainage is impossible by mechanical means. I think this definition ought to be adhered to, because the results from such an infection are different in every respect from the results of infections with drainage into the mouth.

The varieties of periodontoclasia, commonly spoken of as pyorrhea, are, in most cases, in my opinion, symptomatic results of different forms of malnutrition. They are the resultant conditions of diseases in different organs. In certain cases of malnutrition, whether pernicious anemia, general anemia, nephritis, diabetes, etc., the first symptoms to appear—long before uranalysis or a blood examination give definite diagnostic re-

sults—will show in the peridental tissues the effects of such malnutrition. That is especially true in all the different varieties of nephritis; and in this disease pyorrhea becomes a most important diagnostic factor. I have myself diagnosed nephritis, in different varieties in several patients, three or four years before any general internist was able correctly to make that diagnosis; and after such a diagnosis was made by a general internist, too late to afford relief, the patient died shortly afterward in each case.

Another point is the matter of interpretation of dental roentgenograms. The dental roentgenogram can be correctly interpreted only by one who has been efficiently trained in the careful microscopic study of dental tissues. One of the greatest misfortunes that this most valuable thing has brought to us is the presumption, by roentgenologists, that they are qualified to diagnose the conditions they observe. Even the dental roentgenologist is incapable of properly interpreting the average roentgenogram, because the variations in these tissues are so slight, and yet so great, that the diagnosis must be made by a dental practitioner who can draw upon clinical knowledge of the conditions in that mouth, for that purpose. All who repeatedly interpret these pictures know how many puzzling little variations occur in them. I receive many such pictures from all parts of the country. Only last week, I received about twenty from one of the most eminent dentists in southern California, asking for my opinion. I could not give an opinion—and I believe I am justified in thinking I can interpret dental roentgenograms as correctly as anyone. I wrote to him to the effect that, without a more thorough knowledge of the *clinical* conditions, I would not presume to give an opinion.

A paper in a recent issue of this JOURNAL[1] presents a "diagnostic chart" with reproductions of roentgenograms of diseased teeth. I have discussed this chart and its indicated diagnoses with a number of the best interpreters of dental roentgenograms, in this city. We all agreed in our interpretations of those pictures, but none of us agrees with the interpretations recorded by the author of that paper, who is not a dentist and is not qualified to make diagnoses of dental diseases. I am a physician and have practised medicine on all parts of the body at various times. I have handled the x-ray for over twenty years. I believe I can correctly interpret dental roentgenograms. I would not think, however, of interpreting a roentgenogram of any part of the body beyond the region of the dental tissues.

I have spoken of this matter before. I think it is encumbent upon our society to take some action, in this matter, to guard our patients, who are unprotected at present; because physicians are sending patients to roentgenologists who, despite their incompetence, offer diagnoses of dental conditions, which, in many instances, are absolutely false and wholly unjustified.

Dr. Barker: Drs. Gillett, Darling, Shields and Rhein spoke so kindly of the paper, that I can only thank them for their consideration. I expected to be much more severely dealt with!

I was pleased with what Dr. Gillett said about the education of undergraduates. It is important that both medical students and dental students should be informed of the inter-relations of medicine and dentistry. A persistent effort should be made, in both the medical and dental professions, to drive the recognized truths home in order that people may profit by them. The practising profession, both in medicine and in dentistry, must be kept abreast of advancing knowledge.

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[1] Darling: JOURNAL OF DENTAL RESEARCH, 1919, i, p. 391.

Dr. Gillett spoke of some perplexities in his own practice, and put two cases up to me for diagnosis. Dr. Rhein has helped me out very much in giving an answer, for he was unable, he said, to decide in one case, even after he had seen a roentgenogram of the suspicious tooth. Dr. Gillett has asked my opinion upon two cases without even showing me the roentgenograms!

Dr. Gillett: There is a generally foul condition about the two teeth, but they are functioning teeth. The patient has been carrying them about as they are for fifteen years, and is in perfect physical condition.

Dr. Barker: I have no doubt that the decision arrived at by Dr. Gillett was the wisest one possible in the circumstances. We all meet with situations in which it is really difficult to decide upon the best course of action.

As to the existence or non-existence of periodontal infection, I may say that I am always guided by the expert dentist's opinion. If periodontal infection really exist, I think, it should be gotten rid of. I have been so impressed by people who, after they have developed a severe arthritis or a viridans endocarditis infection, and have learned the seriousness of it, have said: "My God! why didn't someone prevent this for me," that I myself have felt that prevention is most important. If I learned that I had definite periapical granulomata in my own mouth, I should want to have them out within a week, for fear of the consequences that might follow if they were retained. It is much better to prevent a disease than to wait for it to develop and then to try to cure it. I think we often have to put the matter of extraction up to the patient. We may have to say: "Here is such and such a condition. Experience teaches us that, if such a condition be allowed to continue, you may get an endocarditis, an anaemia, or an arthritis, though you may carry these infected teeth for the rest of your life and not develop metastatic infection. Shall we remove the threat, or are you willing to take the risk of non-removal?"

Tonight I have emphasized so much the foci of infection in the mouth that it is important to mention at least other possible foci. In arthritis, etc., we should search for all possible foci of infection; sometimes we find three or four existing simultaneously, in which event we should try to get rid of all of them. It is not wise to temporize, removing at first one and then waiting a few months before removing another; and then waiting again for another few months before getting rid of another. It is best to get rid of all of the demonstrable foci of infection as soon as possible after their existence has been detected.

The paranasal sinuses (including the antra, the frontal sinuses, the sphenoidal sinus and the ethmoid cells), the mastoid cells, an old "running ear," infected tonsils, infected adenoids, a chronic appendix, an infected gall bladder, a chronic pyelitis, a ureteritis, a cystitis, an infected prostate, seminal vesicutitis, and (in women) an infected cervix, or endometrium, a pus tube, or an infected Bartholin's gland, are some of the sites other than the teeth and gums that we always examine for focal infection when we suspect that such infection must exist somewhere in the body.

Dr. Darling has emphasized the importance of a physician's never forgetting to examine the teeth when making a general diagnostic study. I think that is very important. Every patient should have his mouth carefully investigated as a part of the general survey.

I was interested in the emphasis laid by Dr. Shields upon calcification within the dental pulp as a possible cause for trigeminal neuralgia, and I shall study my cases of neuralgia from now on with that point also in mind.

Dr. Rhein has given me several things to think over. He drew attention especially to the diseases of the teeth and gums that may be secondary to disease elsewhere in the body. I have been emphasizing the importance of conditions that are primary in the teeth and gums, and of their relations to secondary disease elsewhere. I confess that I have not paid as much attention to the reverse as I should, and I shall be interested in seeing how much can be learned from the point of view Dr. Rhein has mentioned.

We all agree in securing the closest coöperation of physicians, dentists, and roentgenologists. There should be regular conferences of members of the three groups. We can all learn from one another. The expert roentgenologist and the expert dentist can teach us internists much; and you who are dentists will, I know, be glad of any help that roentgenologists and internists offer you. We must all be grateful to one another for the help that each brings for the solution of a common problem.

My own experience with vaccines, in relation to pyorrhea, infected teeth, and secondary metastatic infections, has not been very encouraging. I have had very little success with them. I have used autogenous vaccines frequently, but, so far as I could see, with but little if any benefit, except in gonorrheal arthritis and in furunculosis.

Of course, many cases of endocarditis get well. Only relatively few cases of endocarditis are due to Streptococcus viridans. Most of them are due to the virus of acute articular rheumatism. A few are caused by other bacteria. In the viridans endocarditis that I referred to, the diagnosis was based upon the local heart signs and the positive blood culture. In the series of cases, I mentioned, a positive culture of Streptococcus viridans was obtained from the blood in each. I have, I am sorry to say, never seen one of these get well.

Dr. H. J. Kauffer (New York City): Are most cases with pyogenic organisms in the blood fatal?

Dr. Barker (in conclusion): Not in my experience. The viridans cases die. Endocarditis with the Streptococcus hemolyticus in the blood may not be fatal. In ordinary lobar pneumonia, there are always a few pneumococci in the blood, as we can demonstrate by injecting some of the blood into rabbits, which then die of pneumococcic septicemia; but the patients, as you know, often get well. A few cocci in the blood do not necessarily mean that there will be a fatal termination. A large number of pyogenic cocci in the blood indicates greater gravity, and a worse prognosis.

Too much can scarcely be said about the importance of the prevention of the development of foci of infection. You gentlemen are doing much good in educating the public to prevent the conditions that lead to the death of teeth and later to oral sepsis. You are encouraging the people to visit you often enough to ensure that dental caries shall not go far enough to make it necessary to remove the pulp. No matter how aseptically you treat root canals, some of them, I suppose, will, sooner or later, become infected, and granulomata will gradually develop, to the menace of the patient.

Let me, in closing, express my own great debt to the dental profession, not only for the help they have been to me in keeping well myself, but also for the help they have been to my growth in the recognition of the relations of dentistry to internal medicine. I owe a debt of gratitude especially to several of our dentists in Baltimore. Drs. Grieves, Coriell, Kelsey, Brun, Streett, Baish, Strasser, and others, have taught me the great importance of careful dental work, and I want to go on record as expressing to them my grateful appreciation.

II. JOINT MEETING OF THE SECTIONS ON PATHODONTIA AND PERIODONTIA

Joint meeting of the Sections on Pathodontia and Periodontia, December 29, 1919. Presiding officer: M. L. Rhein, Chairman of the Section on Pathodontia.

Scientific proceedings. Paper by A. Hopewell-Smith, Sc.D., L.R.C.P., M.R.C.S., L.D.S., Professor of Dental Histology, Histopathology, and Comparative Odontology, School of Dentistry, University of Pennsylvania, Philadelphia, on "*human cementum*" (page 59). *Discussion* by Drs. H. J. Kauffer, George Evans, Sr., W. D. Tracy, L. M. Waugh, Theodor Blum, M. L. Rhein, F. S. McKay, Louise C. Ball, N. T. Shields, and I. Hirschfeld, of New York City; and Dr. Hopewell-Smith (this page).

DISCUSSION OF DR. A. HOPEWELL-SMITH'S PAPER ON "HUMAN CEMENTUM" (PAGE 59)

By Drs. H. J. Kauffer, George Evans, Sr., W. D. Tracy, L. M. Waugh, Theodor Blum, M. L. Rhein, F. S. McKay, Louise C. Ball, N. T. Shields, and I. Hirschfeld, of New York City; and Dr. Hopewell-Smith

Dr. H. J. Kauffer (New York City): Dr. Hopewell-Smith's statement that there is no vascularity in the cementum is undoubtedly correct. However, I do not think that that fact means there can be no nutrition in the cementum. I believe there is diffusion into and through the cementum. What is Dr. Hopewell-Smith's opinion on this point? I have sealed the apical third of extracted devitalized teeth and then, submerging them to the enamel edge in a solution of methylene blue, have found that the blue pigment passed through the cementum. Of course, that result was obtained with extracted teeth, but it seems probable that similar permeability exists in the cementum under natural conditions.

Dr. George Evans, Sr. (New York City): I am an old pupil of Carl Heitzmann's. My experience with him dates back to thirty years ago. Heitzmann maintained that there is circulation not only in "dead" teeth and in the pericementum, but even in the enamel itself. There is not an active circulation, but certainly there is diffusion through those tissues. When we hold an extracted tooth to the light, we see that the whole area at the apex is cementum. That cementum, in some way, gets the substances that are in circulation there—some of them are circulated through it.

I want to ask Dr. Hopewell-Smith if he believes that cementum is wholly without vitality. I contend that it has vitality and that there must also be some in the enamel. We know that the enamel on a tooth, which has been without a pulp for a number of years, changes in character. The enamel loses its strength, becomes brittle, and can be cut with a chisel. Are not these changes the consequences of a loss of vitality in the enamel due to the removal of the pulp?

Dr. W. D. Tracy (New York City): I am not competent to discuss this subject. It seems to me, however, that we ought to understand each other and our essayist before we go into a discussion with him. It occurred to me that possibly Dr. Evans had misunderstood something Dr. Hopewell-Smith said, for Dr. Evans intimated that the essayist said that cementum is not a vital tissue. As I understood it, Dr. Hopewell-Smith said that cementum has no *vascular* circulation or *lymphatic* circulation. When a tooth is in situ, it has a certain circulation—a circulation by diffusion at least. This fact has been shown by various observers.

Dr. L. M. Waugh (New York City): It is always a pleasure to meet in person one from whose writings one has learned a great deal. In listening to Dr. Hopewell-Smith this evening, my mind ran back to 1896–97 when I first saw his book on dental microscopy, and, later, to the time when he gave us his book on the pathology of the teeth, which presents, I believe, the most beautiful and perfect illustrations of dental structures ever published.

I have studied the more or less orthodox histology of tooth structure, especially of dental cementum, and I have been teaching dental students for some years. We have recognized in the hundreds of sections made by the students that the cervical two-thirds of the cementum is a thin layer, and is almost devoid of lacunae and canaliculi (they occur only occasionally). In the cervical third, however, the cementum is much thicker, and varies in thickness from 1 micron to 250 microns. I am under the impression that cementum is commonly about $\frac{1}{15}$ of an inch. I have always thought cementum of this degree of thickness is normal cementum, but Dr. Hopewell-Smith regards this thickness as an indication of hyperplasia.

Some of the things Prof. Hopewell-Smith has told us tonight make me believe I have either misunderstood him, or he has undergone a change of heart, because I do not think he believes that teeth without pulps are really "dead" teeth. I cannot believe that a man of his knowledge and sane judgment will lead us to feel there are conditions about the roots of a pulpless tooth that would militate against physiological function there, provided we have guarded against such a result, after removing the pulp, by hermetically sealing the canal and leaving the rest to nature.

Does Dr. Hopewell-Smith believe there is anything physiological or histological about the periapical tissues of a pulpless tooth that would militate against its longevity, provided due precaution has been taken against the occurrence of infection in them?

Dr. Theodore Blum (New York City): I am afraid I cannot add anything of value to the discussion, although I am very much in accord with Dr. Hopewell-Smith's teachings. I should like to ask what term should be applied to a tooth from which the pulp has been removed. You cannot call it a vital tooth, after the pulp has been removed.

Dr. Evans: I should say a *pulpless* tooth. I think it is almost unprofessional to say "dead" tooth.

Dr. Rhein (from the chair): I think Dr. Evans has put the matter exactly. I am going to ask Dr. Hopewell-Smith to tell us which of the specimens he showed tonight were "ground" and which were "decalcified." I believe that some of the differences of opinion in this field will be found to depend largely on variations in the histological technique. The difficulty of maintaining in histological preparations the conditions existing in the teeth is exceptional.

A Member: I should like to ask Dr. Hopewell-Smith to tell us why he thinks the lacunae are devoid of circulation.

A Member: Is the nourishment of the tooth derived entirely from within?

Dr. Frederick S. McKay (New York City): I find myself in much the same position as Dr. Waugh, in learning that normal cementum has no lacunae. The orthodox teaching has created in all of us the belief that lacunae and canaliculi are present in normal cementum. If I understand Dr. Hopewell-Smith, they occur only in hyperplasic cementum.

I should like to ask a question about conditions at the place where the cementum and dentine do not quite join, and where a small amount of dentine is consequently exposed. Does that condition superinduce to what we ordinarily call cervical decay? It explains very clearly the occurrence of cervical sensitiveness, which has puzzled many of us.

Dr. Hopewell-Smith: It is very difficult to reply to every question that has been asked, and every point of view that has been raised. What I have said tonight I have said in perfect good faith. I believe it represents the truth, so far as our knowledge now extends.

Some of the sections were prepared by grinding between stones, and others by decalcification. Where a soft tissue was associated with a hard tissue, the whole was decalcified.

Osmotic force was spoken of by Dr. Kauffer, in regard to devitalization. He mentioned experiments with methylene blue. You can get diffusion of methylene blue into enamel by using suitable means. I believe you can get it into a stone. There is nothing solid that I know of that could not be impregnated by such a stain. I believe if one got sufficient pressure, one could get a stain into steel.

Dr. Rhein (from the chair): Might the stain enter enamel by way of the circulation? If I understand your point of view, the stain would not enter enamel if the pigment were injected into the circulation?

Dr. Hopewell-Smith: Enamel cannot be stained by way of the blood circulation.

Dr. Louise C. Ball (New York City): Dr. Gies has tested that possibility in various kinds of animals. While a student in his laboratory six years ago, I saw some of his results in this connection. He found that trypan blue passes into practically all the tissues after intraperitoneal injection of the stain, but that the pigment does not diffuse into the enamel, unless the enamel is in process of formation while the dye is in the circulation. Dr. Gies found that trypan blue passes, after intraperitoneal injection, from the pulp into the dentine, though in variable ranges of approach towards the enamel; also, through the cementum into the dentine.

Dr. Hopewell-Smith: The enamel of pulpless teeth was spoken of as being brittle and different in character as compared with the normal. That is true. The change in the enamel is due to physical changes in the dentine, which shrinks and causes a physical deterioration in the enamel itself.

Dr. N. T. Shields (New York City): Why should the alveolar bone waste away as extensively as it does, about vital teeth with pulps that are strongly calcified, if there are no lacunae in the cementum? By removing the pulp, however, the alveolar bone can be prevented from disintegrating. Inability of the blood to circulate must be an influence in this connection—an influence that must be reflected to the cementum, or else the alveolar process would not be absorbed.

Dr. Hopewell-Smith: I quite agree with Dr. Evans in regard to the term "dead" teeth. We should speak of "pulpless" teeth, instead.

In response to Dr. Tracy's remarks to the effect that the cementum is not vascularized, I wish to say that cementum is vitalized, in a sense, because it is in contact with a tissue which is in itself semi-vascular. You cannot say dentine is altogether alive; it is not alive, it is semi-vitalized by the exudation of lymph into its tubes. Cementum contains no tubes. It is difficult to conceive of it as being vitalized. It is practically a dead tissue.

I thank Dr. Waugh for his kind references to my work. I should have said, as he did, that cementum is about $\frac{1}{16}$ of an inch in thickness, if I had not measured it. I was surprised myself when I found that it is much thinner. It is about $\frac{1}{100}$ of an inch thick, normally, but there are many pathological deviations from this thickness.

I am ready to make "a change of heart" when it is necessary. I endeavor to keep an open and progressive mind. I made some statements which perhaps are rather dogmatic, but I am trying to give you what I believe to be the truth in regard to these matters.

I believed for many years, because I had been so taught, that lacunae are normally present in cementum. I have found lacunae in thousands of sections of cementum. I am accumulating data on this point and will some day publish them. I am convinced however, that lacunae do not exist in *normal* cementum, and that their occurrence in this tissue is evidence of hyperplasia of it. The thinness of normal cementum will not permit of the presence of lacunae.

The absorption of the alveolar process begins at a very early age, and may be attributed to influences entirely independent of the teeth. The alveolar tissue has no muscular attachments excepting the buccinator. The result is a functionless bone, and a slow disappearance occasioned by physiological absorption.

Dr. I. Hirschfeld (New York City): I believe that, in treating dental periclasia, we get attachment of the surrounding tissues to the root surfaces, very often in cases where the peridental membrane has entirely disappeared, clinically speaking. I should like to know how it is, that, if the vitality of the cementum is as low as Dr. Hopewell-Smith intimates, this attachment of soft tissue to the root surfaces occurs.

Dr. Hopewell-Smith (in conclusion): In my paper I stated that the connection is probably by a cicatricial tissue, but I cannot tell just how the union between the soft tissue and the root is developed. It is perfectly clear that we get some attachment, but I think it is merely a mechanical attachment to the cicatricial tissue. The shapes of the roots, and sclerosis of their sockets in chronic inflammatory conditions, are also contributory factors.

III. MEETING OF THE SECTION ON PERIODONTIA

Meeting of the Section on Periodontia, March 29, 1920. Academy of Medicine, New York City. Presiding officer: Frederick S. McKay, Chairman of the Section.

Scientific proceedings. Paper by Arthur Zentler, D.D.S., Instructor in Oral Surgery, Advanced Courses in Dentistry, Columbia University, New York City, on "*the surgical treatment of suppurative gingivitis, so-called pyorrhea*" (page xvii). *Discussion* not reported.

THE SURGICAL TREATMENT OF SUPPURATIVE GINGIVITIS, SO-CALLED PYORRHEA[2]

ARTHUR ZENTLER

New York City

For the benefit of those who may wish to learn why I continue to use the surgical method I devised for the treatment of suppurative gingivitis (commonly known as pyorrhea),[2] I wish to call attention to the fact that it is a well established axiom in surgery that the only way to eradicate infection is to gain full and free access to the infected part; and that, in order to obtain such access, one must unhesitatingly lay wide-open the region affected. Modern surgery is guided by this axiom in all cases except those in which such a procedure would damage vital organs or endanger life itself. I am sure that the use of my method does not damage a vital organ or endanger life. Consequently, the surgical axiom mentioned above should be followed in this field of surgery as it is in all others.

So far as I am aware, my critics propose only two objections to the use of my method. One objection is the fear that the lifting of a flap may lead to permanent detachment of the soft tissues from their hard under-structure at the gingival margin and thereby create a further cause for pathology. The other criticism, widely heralded by men who practise the speciality of periodontia, is the opinion that satisfactory results can be obtained by what are called "less heroic" means.

To the latter opinion I reply that my critics have never proved it to be justified, unless they refer to cases of so-called pyorrhea that are not nearly so far advanced as those in which suppuration *can* be promptly and permanently eradicated by the flap operation. Even for cases which are not very far advanced, however, (a) successful and permanent cure can be effected by the flap operation in a small number of sittings—the patients are usually dismissed on the tenth or twelfth day after the date of the operation; (b) the operation is done, without pain to the patient, under conductive anesthesia; and (c) 95 per cent of the number of cases report "practically no discomfort" after the operation. These facts should be sufficient to justify the use of my method of treatment, in preference to the methods that require a larger number of visits, and which, if I am correctly informed, are now employed by a majority of the men who treat such cases without anesthesia, and who, thereby, inflict a great deal of unnecessary pain.

[2] The author has presented, for publication, only the *introductory* portion of the paper. The method he mentions was described by him in the *Journal of the American Medical Association*, 1918, lxxi, p. 1530; *Dental Items of Interest*, 1919, xli, p. 182; and *International Journal of Orthodontia and Oral Surgery*, 1919, v, p. 586.

As for the fear of lack of reattachment of the soft parts to their underlying hard structure, etc., I desire to say that this apprehension can be felt by those only who have not gone to the trouble, or taken occasion, to examine some of the many cases I have presented at clinics, in this city and in various other parts of the country. At these clinics patients were exhibited at the ends of periods ranging from a few days to several years after my operation had been applied to them. Dentists who have seen some of these cases are fully convinced that reattachment is as perfect as normal gingival attachment, and that it has remained so, years after operation, in persons treated by my method for very extensive suppurative gingivitis. What is most remarkable, and should be of special interest to every dentist, is the fact that this perfection of reattachment occurs in mouths where neither the occlusion nor the number of existing teeth meet the supposed requirements for a healthy condition and appearance of the gingiva. Neither can it be said that the patients, shown by me after treatment, are of the kind who could indulge in extensive prophylactic care of their mouths either by themselves or their dentists. Most of these patients confess to using brush and powder only twice daily; sometimes, only once.

IV. ANNOUNCEMENT BY THE ORAL HYGIENE COMMITTEE OF THE FIRST DISTRICT DENTAL SOCIETY OF THE STATE OF NEW YORK

ARTHUR ZENTLER

Secretary

The ordinance passed by the Board of Aldermen of New York City and signed by Mayor Hylan, providing for an appropriation of $50,000 for the maintenance of nine additional free dental clinics in public schools and for salaries for eighteen additional dental hygienists in these clinics,[1] was recently reviewed by the Finance Committee of the Board of Estimate and Apportionment, and the action of the Aldermen, in effect, rescinded.

At a public hearing, on March 15, an effort was made, by speakers representing various dental organizations, to show cause for approval, by the Finance Committee, of the action of the Aldermen in appropriating $50,000 in behalf of the furtherance of preventive dentistry in the public schools. The Committee was unable, however, to change its adverse vote.

It is hoped that, by renewed efforts in the fall, on the part of dental, medical, and philanthropic organizations, the municipal authorities will be persuaded to vote unanimously in favor of the proposed measures for the promotion of the public welfare through the agency of an increased number of free dental clinics in the public schools.

[1] Zentler: JOURNAL OF DENTAL RESEARCH, 1919, i; Proceedings, p. cxlii.

PROCEEDINGS OF THE HARVARD ODONTOLOGICAL SOCIETY

EUGENE B. WYMAN, *Editor*

Meeting held November 20, 1919. Young's Hotel, Boston, Mass. Harry S. Parsons, D.M.D., president pro tem., in the chair.

Scientific proceedings. *Paper* by J. Campbell Thompson, D.M.D., Boston, Mass., on "*speed, efficiency, and painlessness, in tooth-cavity preparation*" (this page). *Discussion* not reported.

SPEED, EFFICIENCY, AND PAINLESSNESS, IN TOOTH-CAVITY PREPARATION

J. CAMPBELL THOMPSON

Boston, Massachusetts

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INTRODUCTION

From the patient's standpoint, dentistry, at best, is an unpleasant performance. How this can be changed to a large degree, will be suggested later. The call for expeditious handling of patients, by reduction in the amount of time spent by them in our operating chairs, is one to which we shall have to respond, sooner or later. Suggestions which, if executed, would conserve the time of both patient and operator should have special consideration.

Napoleon, in letters to his brother referring to organization and system in managing armies, said:

"For everything you must have a plan; whatever is not profoundly considered in its detail produces no good result. I trust nothing to chance. There is a great difference between organizations with a well considered system, from an organized centre, and operations proceeding at hazard without such a centre. You will not be successful without a system nor without bestowing the greatest attention upon it."

System, as devised by Angle and others, has, to a large extent, made orthodontia the splendid specialty of dentistry it is today. System, as advocated by Callahan, Best, and others, has made root-canal work a more dependable and definite procedure. System, as about to be considered, should, and will, to a large extent, make unnecessary the employment of the root-canal procedure, because more teeth will be permanently preserved by proper cavity preparation, contouring, surface marking—that is, carving the morsal surface of the filling, and reproducing the condition that would be normal for that location. In brief, we should get away from the old smooth-top fillings—stoppings, as the English have called them; and they are well named unless that term be too mild. We should produce genuine restorations.

When the word system is mentioned in connection with operative dentistry, the name, Black, immediately comes to mind, for to the memory of G. V. Black we owe tribute for the only real system ever devised for the preparation of cavities in teeth—a system so planned that two operators familiar with it may operate independently and alternately upon the same cavity and each operator will spontaneously take up the work where the other left off and will use the very instrument the other operator would have used had he continued.

"Cavity preparation includes all those operations required for the removal of carious material from cavities formed in the teeth by decay, forming the cavities for the reception of fillings, and such extensions and preparations as will best fit the affected surfaces of the teeth to resist decay in the future." (Black: The technical procedures in filling teeth.)

CLASSIFICATION OF TYPES OF CAVITIES

Five classes of cavities are recognized. There is a definite mode of preparation for each class. Once the preparation for each class is thoroughly understood, the results become almost automatic. Nothing is left to chance; and especially does this apply to retention, to frail walls, and to impressions in the case of inlays.

"In a classification of cavities," quoting Black, "it is the intention to group together, in classes, cavities of decay that require a similar line of treatment, in order that these may be more closely associated.

"*Class 1.* Cavities beginning in structural defects in the teeth, as in pits and fissures.

"*Class 2.* Cavities in the gingival third—not pit cavities—of the labial, buccal, or lingual, surfaces of the teeth.

"*Class 3.* Cavities in the proximate surfaces of the incisors and cuspids which *do not* involve the removal and restoration of the mesial or distal angle.

"*Class 4.* Cavities in the proximate surfaces of the incisors and cuspids which *do* require the removal and restoration of the mesial or distal angle.

"*Class 5.* Cavities in the proximate surfaces of the bicuspids and molars.

"*Class 1.* Pit and fissure cavities. These cavities are located in the occlusal surfaces of the bicuspids and molars, in the occlusal two thirds of the buccal surfaces of the molars, in the lingual surfaces of the upper incisors and occasionally in the lingual surfaces of the upper molars. They are all pit or fissure cavities. They occur in surfaces of the teeth that are habitually clean, except as imperfections of the enamel in the form of pits and fissures afford an opportunity for the lodgment and fermentation of debris which causes the beginning of decay. Therefore, the enamel surfaces immediately about the cavity being habitually clean, none of them requires extension for the prevention of the recurrence of decay in their preparation for filling. All that is required is to remove sufficient enamel completely to uncover the carious area and to obtain margins sufficiently level and smooth to give opportunity for a perfect finish of the filling.

"*Classes 2, 3, 4 and 5* are all smooth-surface cavities. They all occur in positions in which the surfaces of the teeth are unclean habitually, and usually have their beginnings in the central portion of the unclean area, with a tendency of the carious action to spread superficially upon the enamel surface. They all agree, therefore, in requiring extension for the prevention of the recurrence of decay in such a way as to include within the lines of the enamel margins of the prepared cavity all of that portion of the surface especially liable to decay."

ORDER OF PROCEDURE

General technique

"Obtain, in the order indicated, the required (1) *outline* form, (2) *resistance* form, (3) *retention* form, and (4) *convenience* form. Then (5) remove any remaining decayed dentin. (6) Finally, (a) correct the form of, and (b) smooth, the enamel wall; (c) bevel the cavo-surface angle; and (d) make the toilet of the cavity.

"The careful observance of this order of procedure will greatly facilitate the operation, lead to a more careful consideration of the requirements in individual cases, and will guide to the use of the appropriate instrument for the different parts of the operation."

A complete set of instruments has been designed to cover every possible phase of cavity preparation, so systematized that, from beginning to end, each step is planned in advance. The decayed material is not removed from the cavity until practically everything else has been accomplished. A system of naming the instruments was devised. The metric system was used. The width of the blade is given in millimeters, the length of the blade in millimeters, and the angle of the blade to the shaft of the instrument is given in centigrades. Forty-four instruments comprise the full set.

Accessibility

What accessibility means to the root-canal worker surely is self-evident. Overhanging walls of the tooth structure, which obscure light or vision, must be sacrificed to the larger purpose of thorough root-canal surgery. The sacrifice of tooth substance is no less urgent in the preparation of a difficult cavity. Practically all difficult cavities can be made simple when treated with this plan in mind.

Type of filling

Cavity preparations are easily altered from the filling type to the inlay type, or vice versa.

Retention

There is a definite mechanical procedure in the matter of retention, for each type of cavity. There should be no weakening of the enamel walls for retention, no infringement upon the pulp area. No chance should be taken that the filling will not stay. Retention may be made, therefore, a definite condition.

Resistance

A weak portion of a tooth is strengthened because the point of stress is transferred from frail walls to a solid base, that is, a flat cervical area and a flat pulpal seat are the rule.

Speed

The instruments are definitely marked. The various figures on the handles indicate the uses for which the instruments were planned. Each instrument having its properly marked place in a cabinet, the operator finds an instrument without loss of time. An assistant likewise places instruments without loss of time. By the use of the superheated-steam method of sterilization, the operator has his full equipment before him practically all the time, though, of course, duplicates are provided.

Results

Typical cavities, prepared by Black's method, do not result in fracture of the teeth, nor in unnecessary waste of good tooth substance, nor in undue pain. Fillings last longer, function better, preserve interproximal spaces, do not cause Riggs' disease, and avoid apical involvement.

Much of the non-acceptance of Black's teaching is ascribable to his not being understood. He is misunderstood, not because he has not described his method clearly enough, but because the method cannot be learned by glancing through a few articles on the subject or by listening to the reading of a paper on it. The method requires return to the fundamentals of dentistry and *study* of the whole subject.

Efficiency

Efficiency follows as a matter of course where proper attention has been paid to all details. More teeth can be filled per day. There is a larger financial return. There is greater pride and interest in the work. More men aim at the same result. Operators become more proficient. There is more time for thorough examination and filling of *all* cavities.

In the foregoing brief survey I have considered speed and efficiency. A dental operator can scarcely develop efficiency without at the same time becoming a more rapid operator.

ANESTHESIA

Methods

Painlessness is effected by the adoption of system. A definite procedure eliminates uncertainty in action. A sharp instrument designed to do its own special work, and the knowledge of where, when, and how, to use it,

are great factors in reducing the discomfort of the patient. Painlessness may be maintained with greater success now than at any previous time in the history of our profession. Three distinct methods are recognized: topical applications, injections, and the use of nitrous oxide. Complete success and satisfaction may result from the use of any one of these methods, but it cannot be claimed that any one method will always succeed with every patient.

Topical applications

One very useful type of topical application is that which is used on sensitive areas prior to actual cavity preparation. Velvophenox and Buckley's Desensitizing Paste are of this class. They are useful but must be applied with care and good judgment. Chloroform and ether preparations, essential-oil combinations, or carbolic acid, may be used to advantage in certain cases but, for the most part, have been found wanting. Silver nitrate is in a class by itself and, as we all know, does remove sensitiveness—but this is beyond the range of the present discussion. Ethyl chloride, or a blast of cold air at a pressure of 40 lbs., delivered through a nozzle with a small diameter, is very effective in certain types of cavities and for certain patients; and each will definitely control pain.

Injections

Novocaine, and its various combinations under trade names, also remedies similar to novocaine, are very useful, in fact are indispensable, in present-day practice. These anesthetics are specially valuable for neurotic patients, for cases of severely sensitive dentine, and for practically every kind of surgical procedure. Cocaine is used rarely and in vital-pulp removal principally. The desirability of even that use of cocaine is open to question.

Nitrous oxide and oxygen

Nitrous oxide and oxygen together, are one of our most important anesthetics. This combination is useful in place of practically any or all of the other anesthetics. Properly managed by a thoughtful operator, its uses and advantages challenge comparison. In a large percentage of cases, patients, who have always been apprehensive of consequences in dental operations, return with confidence and good cheer after they experience the benefits that may be derived from the proper use of nitrous oxide and oxygen. This anesthetic requires, however, the use of a suitable apparatus. In this there are great degrees of efficiency, some appliances being practi-

cally worthless. The use of this anesthetic calls for training of the operator as well as of the patient, also eagerness and enthusiasm on the part of each for its benefits, if the best results are to be obtained.

Speed and efficient cavity preparation, then, become merely a gauge of the operator's ability, once the patient is placed in the proper stage of analgesia.

CONCLUSIONS

A new day for dentistry has dawned. The present-day public is "educated" in advance of the average dentist.

A better kind of work, which to a greater extent will preclude the possibility of focal infection, is demanded.

Less work, less pain, more and better advice from the dentist, and fees in keeping with the importance of his work, are the order of the day.

Loss of time for our patients, due to poor planning and inefficient management on our part, must be a thing of the past. We must remember that the value of the time of many of our patients far exceeds any value we may place on our own time.

We must educate ourselves to a sense of the great importance of our smallest piece of work and then make our patients realize the ideal for which we are striving. We shall then command their interest and coöperation.

We should make it a point to choose our patients. Not every patient that presents should be given our service. Some patients may not be of a sort to do us credit or to appreciate our standard. Our patients usually make some inquiry before choosing us. Why should we not require references of them?

We should take more time for examination, consultation, and a study of our cases, with conservation of the health of our patients uppermost in our purposes. Then, when our mature judgment is revealed, we should charge a fee that is in keeping with the importance of the service rendered and not based merely upon the sale of gold, silver, rubber, or even hours.

Finally, if, after every other means fails and we are called upon to construct a piece of plate-work, the so-called "wooden leg of dentistry," it is not too much to hope that our patients will be given substitutes that will conceal the art in our work on them by being more natural in appearance, more useful in enunciation, and more harmonious with facial contour —in other words, more efficient.

Speed, efficiency, and painlessness, are most desirable to attain, but the greatest of these is efficiency.